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ABSTRACT

This curriculum guide, part of a series of curriculum guides dealing with industrial electricity and industrial electronics, is designed for use in teaching a course in applied industrial electronics. The first half of the guide contains units on remote sensing devices and the industrial uses of transducers. The second part of the course, consisting of six lessons devoted to logic systems, covers the meaning of the term binary, binary logic, binary codes, counters, memory circuits, and systems and interfacing. Each instructional unit contains some or all of the following: performance objectives, suggested activities, information sheets, transparency masters, assignment sheets, job sheets, tests, and answers to the test and assignment sheets. (MN)

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Applied Industrial Electronics

Sensors and Logic Systems

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Curriculum and Instructional Materials Center

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APPLIED INDUSTRIAL ELECTRONICS
SENSORS AND LOGIC SYSTEMS

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FOREWORD

In Oklahoma, vocational educators have a basic belief that quality vocational programs require the use of sound instructional materials. A comprehensive approach with a quality treatment served as the primary objective when the Oklahoma State Department of Vocational and Technical Education, Curriculum and Instructional Materials Center began development of educational products for industrial technology. Materials now exist for several specialty fields, including pneumatics, hydraulics, industrial electricity, and industrial electronics. This volume, *Applied Industrial Electronics: Sensors and Logic Systems,* supplements *Introduction to Industrial Electricity-Electronics* and *General Industrial Electronics.* For students interested in the industrial electronics field, further study is provided in *Applied Industrial Electronics: Power Control and Electronic Troubleshooting.*

Industry representatives, educators, and technical specialists collaborated closely to produce these materials in the hope that students will gain the knowledge and skills required in industrial electronics through practical learning experiences. Coupled with the instructor's own methods and expertise, these materials should prove to be a valuable asset for an industrial electronics program.

It is our sincere wish that the manuals in this series will contribute to the development of a competent, safety-conscious work force in the industrial electronics trade.

Francis Tuttle, Director
Oklahoma State Department of
Vocational and Technical Education

Ivan Armstrong, State Supervisor
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Oklahoma State Department of
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PREFACE

The purpose of *Applied Industrial Electronics: Sensors and Logic Systems* is to build upon the skills and knowledge of industrial electronics gained by the student through the learning activities in the two introductory volumes of this program. Specifically, the student will have the opportunity to expand those skills in two important industrial applications—remote sensing and logic systems.

These curriculum materials have been designed for use in full-time secondary and post-secondary classes, as well as part-time adult classes. The material is easily adaptable to open-entry, open-exit programs to allow students to progress at their individual paces.

A skilled instructor will be able to supplement, personalize, and localize this material to meet specific training needs. The design of the material allows the different topics to be presented in a variety of sequences, and even permits the use of part of a unit of instruction at a given time. The "Use of this Publication" section will greatly aid the instructor and student in getting the most from these materials.

Bob Patton, Coordinator
Curriculum and Instructional
Materials Center
Oklahoma State Department of
Vocational and Technical Education

ACKNOWLEDGEMENTS

Any project as comprehensive and involved as this guideline for teaching industrial electronics requires the contributions of a great number of people. We are thankful for the tremendous support we have received in the development of this book. First, we are grateful to the Oklahoma State Department of Vocational and Technical Education under the direction of Dr. Francis Tuttle, and especially to the industrial technology advisory committee for recognizing the need for these instructional materials.

We worked closely with two of the CIMC assistant coordinators, Greg Pierce and Joyce Sawatzky, who trained us and guided us during the writing process. The primary review committee consisted of several qualified instructors and industrial experts whose contributions were invaluable. The committee included

Wallace Farris
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Bartlesville, Oklahoma

Cecil Hendrick
Maintenance General Foreman
National Standard Company
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Raymond S. Todish
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Jim Wilson
Assistant Superintendent of Adult
Education
Indian Meridian Area Vo-Tech School
Stillwater, Oklahoma

After the writing was completed, several vocational training programs field-tested these materials. Instructors involved in the field-test then met to review the results and suggest revisions. The final draft of these materials owes much to these instructors and industry people who took the time and showed the patience to use the field-test copy of this manual. The committee that reviewed the field-test results included

Charles Herndon
Electronics Instructor
Tulsa County Area Vo-Tech School
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Technical Education Foundation
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Guy Sneed
Industrial Maintenance Instructor
Kiamichi Area Vo-Tech School
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Dwight Snider
Electronics Instructor
Tri-County Area Vo-Tech School
Bartlesville, Oklahoma

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Industrial Electronics Instructor
Central Area Vo-Tech School
Drumright, Oklahoma

We owe a great deal of gratitude to the many people involved in the production process. Robert Hilley served as the project coordinator during the production phase of this project at the CIMC. The entire editorial staff, under Terri Barnes, did an excellent job of reviewing the content and format and getting the final copy ready for printing; thank you Sue Buck, Sue Feasley, Terra McCluskey, Susan Walker, and Jerry Weir. The various drafts of the manuscript were ably produced by Judy DeVaughan of the CIMC secretarial staff, who prepared the rough drafts, and by the phototypesetters in the Communication Center under the direction of Jenny Fowler. Special thanks to Dona Landreth, Rose Primeaux, Gari Sha Robinson, Allison MacLaughlin, and Lori White.

The Art Department, under Carrie Williams, provided the excellent illustrations and graphics that accompany the text. We are grateful especially to Nancy Hilley, Dana Welborne, Carol Crump-Jones, Kim Hale, and Gary Bradley who did the majority of the artwork. The quality of the published product is the result of the care and talents of the Print Shop personnel under the supervision of Noel Wilcoxson. To these and many others, we are extremely grateful because this book would not be possible without the combined efforts of everyone involved.

It is our sincere wish that these materials be of value to instructors in industrial electronics programs and that they benefit those students who are pursuing careers in this vital and rewarding field.

Leo Siebert

Jim Harwick

USE OF THIS PUBLICATION

Instructional Units

Applied Industrial Electronics: Sensors and Logic Systems includes eight instructional units. A standard format was established in 1970 for development of instructional materials for all Oklahoma vocational teachers. This format includes eight basic components that form a unit of instruction: performance objectives, suggested activities for the teacher, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to tests and assignment sheets. Depending on the specific objectives, there may or may not be transparency masters, assignment sheets, and job sheets included in the unit of instruction.

All of the unit components "zero in" on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help him or her determine the following

A. Amount of material that can be covered in each class period
B. Skills that must be demonstrated
  1. Supplies and equipment needed
  2. Amount of practice needed
  3. Amount of class time needed for demonstrations
C. Supplementary materials, such as pamphlets and filmstrips, that must be ordered
D. Resource people who must be contacted

Performance Objectives (white pages)

Each unit of instruction is based on the performance needed for successful employment in an occupational area. Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching/learning process, it is important that teachers and students have a common understanding of the intent of the objectives. Following is a list of performance terms, their meanings, and behavioral synonyms that may have been used in this material.

A. Name — The individual supplies a name for objects, events, or people

   Behavioral synonyms: Label, list, letter, record, reiterate, repeat, write

B. Identify — The individual selects a named, described, or pictured object by pointing to it, touching it, picking it up, or selecting it

   Behavioral synonyms: Select, mark, match, choose, judge

C. State a rule — The individual communicates a relationship or principle that could be used to solve problems or perform a task

D. Apply a rule — The individual supplies an answer to a problem by using a stated relationship or principle

Behavioral synonyms: Solve, calculate

E. Describe — The individual relates sufficient characteristics or properties of an object or event so that a second individual will be able to state what is being discussed

Behavioral synonyms: Define, discuss, interpret, recite, tell how, tell what happens when

F. Distinguish — The individual selects an object or event from two or more that are easily confused

Behavioral synonyms: Discriminate, differentiate

G. Order — The individual arranges three or more objects or events in a sequence based on a stated property

Behavioral synonyms: Arrange, sequence, list in order, classify, divide, isolate, sort

H. Construct — The individual makes a physical object, a verbal statement, or a drawing

(NOTE: *Construct* is used when the finished product or result is important.)

Behavioral synonyms: Draw, make, build, design, formulate, reproduce, transcribe, convert, put together, compile

I. Demonstrate — The individual performs several operations necessary to carry out a specified process

(NOTE: *Demonstrate* is used when it is desirable to watch the student perform a task, one of the highest levels of student performance.)

Behavioral synonyms: Show your work, show procedure, perform an experiment, perform the steps, operate, remove, replace, turn off/on, (dis)assemble, (dis)connect

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Prepare for each unit by deciding how each objective can best be taught.

The objective sheet may also be used as a quick pretest to determine prior knowledge of students and to determine whether further study or activities are necessary. Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When changes in objectives are made, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Suggested Activities (pink pages)

This component is included only in teacher material. The suggested activities page assists teachers during the preparation stage of the teaching/learning process by providing suggestions for delivery and/or presentation during the instructional process. Read the suggested activities before teaching the units to allow time to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

The references that are listed are ones used in the development of each unit. They should be used by the teacher to supplement her or his knowledge of the subject area or to help students with particular interests or occupational objectives in the area covered.

Information Sheet (green pages)

The information sheet provides "must know" content essential for meeting the cognitive (knowledge level) objectives of the unit. The information is written in a topical outline form and is keyed to the specific objectives.

Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. The information sheet may also be used for coordination activities and advisory committees.

Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide motivation for each unit.

Transparency Masters (white pages in teacher material and green in student material)

Transparency masters provide information in a special way. Transparencies direct the class's attention to the topic of discussion. Transparencies may present new information, or they may reinforce information presented in the information sheet. They are particularly effective when identification is necessary. Make transparencies and place them in the notebook where they will be immediately available for use.

Assignment Sheets (brown pages)

Assignment sheets give students a chance at problem solving, self-assessment, and/or practical experience with the information. They assist students in the application of knowledges that are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided when appropriate and can be used by the student and/or teacher for checking student progress.

Job Sheets (blue pages)

Job sheets are another important segment of a unit of instruction. The job sheets provide a list of equipment, tools, and materials needed to complete a manipulative or psychomoter skill. They describe a step-by-step procedure needed to complete each task or job. Diagrams, photographs, and illustrations are provided to assist students in achieving the skill.

Instruments in job sheets are not in order of use. The order of use should be taught in the classroom. In this way, students will not depend entirely on job sheets for instrument setup.

A teacher should demonstrate to students the procedures outlined in each job sheet. Furthermore, the teacher needs to localize the job sheet according to the equipment and supplies available in the local lab or shop situation. Job sheets also furnish potential employers with a picture of the skills being taught and the performances they might reasonably expect from a person who has had this vocational instruction.

Tests (yellow pages)

This component provides criterion-referenced evaluation of every objective listed in the unit of instruction. It is crucial to note that both paper/pencil and performance objectives must be evaluated.

The tests may be written or oral. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of questions from the units covered may be used for final tests at the end of each term if desired. If objectives have been added, deleted, or modified, be sure to make the changes on the test.

The acceptable response on a unit test, 85 percent in most units, may be raised or lowered to fit the topic or students' ability levels. The percentage applies to the overall score, not to each individual question. The final unit grade should be obtained by using the paper/pencil score along with evaluations of student demonstrations of the desired skills.

Answers to Test and Assignment Sheets (pink pages)

These components are designed to assist the teacher in evaluation of student performances.

Page Numbering

Each publication from the Curriculum and Instructional Materials Center is assigned a specific abbreviation. For example, *Applied Industrial Electronics: Sensors and Logic Systems* has been abbreviated AIE. The units are then numbered consecutively within each section. An example of a page number is AIE-1-A. Since CIMC publications are loose leaf, this system of page numbering was adopted so that pages from different manuals would not get mixed up.

Methods of Disseminating Material

Material may be given out a unit or page at a time to keep the material before the student always new. Some teachers ask students to furnish a three-ring binder for the units. This is convenient for taking the materials home to study. Upon completion, each unit is then placed in a larger binder. The large binders may be purchased at cost from the CIMC. Some teachers store the materials by units in filing cabinets or boxes until needed. All the units may be given out at once if desired.

For best results, provide student materials for each student. Student materials contain everything but the test answers, answers to assignment sheets, and suggested activities. All tests are collated at the back of student material and should be removed and stored until needed. Students should be allowed to take their materials home at the end of the year.

Teaching Methods

It is a challenge to keep students motivated. Supplement the objectives by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each objective can best be taught. Allow students to become involved in preparing and planning.

Competency Profiles

Competency profiles are folders used to document student performance. The profile contains a list of the specific job competencies that should be achieved prior to leaving the training program.

CORRECTIONS AND SUGGESTIONS

The Curriculum and Instructional Materials Center wants to provide vocational instructors and students with materials that are accurate and effective. Although the Center strives to maintain the highest standards of development and production, oversights occasionally do occur. If you find any errors in this or other CIMC publications, or have suggestions for improving their usefulness in vocational programs, please notify the CIMC staff. One easy way of pointing out errors is to make a photocopy of the affected page and to indicate the correction on the copy. You can then mail the information to the CIMC, where it will be used to correct the publication before the materials are reprinted.

To ensure that the material is updated on a timely basis, it is important that you notify the Center of necessary corrections as soon as possible after discovering the error. Do not assume that someone else will notice the error and inform the CIMC; other users may be making the same assumption. Please send corrections and recommendations for improving this publication to the following address:

Assistant Coordinator for Development
Curriculum and Instructional Materials Center
Oklahoma State Department of Vocational and
Technical Education
1500 West Seventh Avenue
Stillwater, Oklahoma 74074

REMOTE SENSING
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to demonstrate the ability to construct, test, and troubleshoot elementary remote sensing circuitry. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with remote sensing circuits to their correct definitions.
2. Match abbreviations associated with remote sensing to their correct interpretations.
3. Identify control diagram symbols.
4. State the basic purpose of remote sensing.
5. List applications for remote sensing.
6. Match the basic components of a remote sensing system to their correct descriptions.
7. Label linear and nonlinear signals on graphs.
8. Identify types of remote sensing modulation.
9. Calculate number of output pulses.
10. Identify applications of remote sensing devices.
11. Interpret a flow diagram for a remote sensing circuit.
12. Demonstrate the ability to
    a. Construct a phototransistor remote sensing circuit.
    b. Construct and test a thermocouple circuit.
    c. Construct and test a digital-to-analog converter circuit.

REMOTE SENSING
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

A. Make transparencies.

B. Consult a local industry official to schedule a field trip to look at remote sensing systems.

C. Contact industrial representatives and vendors. See if they have transducers and other remote sensing system components that, even if defective, could be shown to students.

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and assignment sheets.

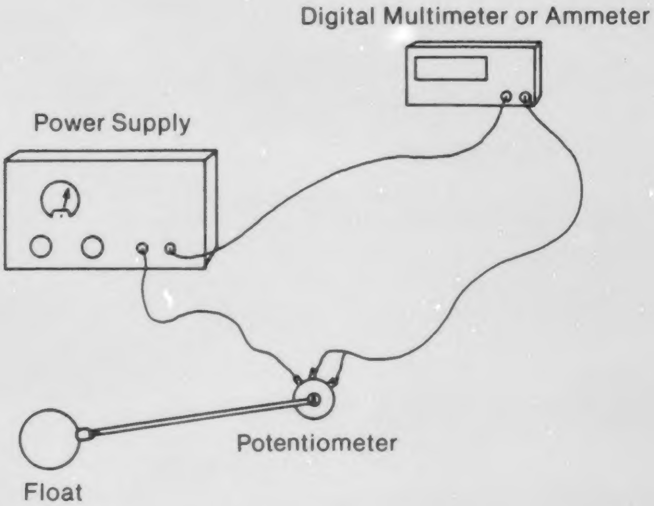
G. Discuss information and assignment sheets.

H. Have students point out remote sensors in the classroom, automotive shop, etc.

I. Provide students with job sheets.

J. Demonstrate and discuss procedures outlined in job sheets.

K. Construct a model of a liquid-level remote sensor by attaching a rod and float to a potentiometer shaft, and connecting a power supply and ammeter as shown in the figure below.

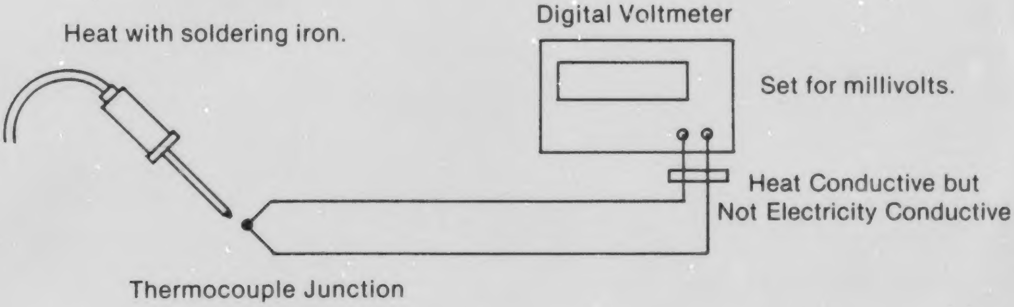


SUGGESTED ACTIVITIES

L. Demonstrate the thermocouple effects of ganging, cold junction referencing, and various dissimilar metals.

M. Set up the circuit shown in Job Sheet #1 and make a rotating disk out of something simple like a paper plate. Connect the disk to a small variable-speed drill motor. Turn out the classroom lights, and rotate the disk between the lamp and the phototransistor. Show the frequency variable effect on the oscilloscope.

N. Construct a model demonstrator of a simple remote sensing circuit as shown in the figure below.


Heat with soldering iron.
Digital Voltmeter
Set for millivolts.
Heat Conductive but
Not Electricity Conductive
Thermocouple Junction

O. Give test.

II. Instructional materials

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM #1 — Remote Sensing System
2. TM #2 — Linear Signal
3. TM #3 — Nonlinear Signal
4. TM #4 — Turbine Meter

SUGGESTED ACTIVITIES

D. Assignment sheets
   1. Assignment Sheet #1 — Calculate Number of Output Pulses
   2. Assignment Sheet #2 — Interpret a Flow Diagram for a Remote Sensing Circuit

E. Answers to assignment sheets

F. Job sheets
   1. Job Sheet #1 -- Construct a Phototransistor Remote Sensing Circuit
   2. Job Sheet #2 — Construct and Test a Thermocouple Circuit
   3. Job Sheet #3 — Construct and Test a Digital-to-Analog Converter Circuit

G. Test

H. Answers to test

III. Unit references

A. Cooper, William David. *Electronic Instrumentation and Measurement Techniques.* Englewood Cliffs, New Jersey: Prentice-Hall, 1970.

B. Robertson, Paul L., and George S. Amsbary. *Basic Electronics II, A Curriculum Manual.* Santa Fe: The Vocational-Technical Division of the New Mexico State Department of Education, 1974.

(NOTE: This manual is available from the Mid-America Vocational Curriculum Consortium, Inc., 1500 West Seventh Avenue, Stillwater, Oklahoma 74074.)

REMOTE SENSING
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Accuracy — Instrument's ability to measure the actual or theoretical value of a parameter

B. Calibration — Instrument adjustment so that a specific input produces a required output over the intended operating range

(NOTE: An instrument may be accurate but not be calibrated properly.)

C. Resolution — Instrument's ability to produce measurable changes in outputs as a result of measurable changes in inputs

D. Transducer — Device that converts energy from one form to another at known and consistent rates

EXAMPLE: A piezoelectric crystal is a transducer because it converts pressure energy directly to electrical energy.

E. Resistive thermal devices — Resistors that vary with temperature and are used as temperature sensors

F. Summing circuit — Electronic device that combines two or more analog signals into a single output

G. Thermocouple — Temperature-sensing device made of the junction of two dissimilar metals that produce a small voltage related to the ambient temperature at junction

H. Solenoid valve — Electrically operated valve that opens or closes to control fluid or gas flow through pipes

I. Control valve — Valve that can be at various stages between open and closed to adjust the fluid or gas flow through pipes

J. Turbine meter — Rotating blades that produce an electronic signal that represents the quantity of fluid or gas flow through pipes

K. Motor tachometer generator — Generator attached to a rotating machine in order to monitor rotational speed

L. Linear variable differential transformer — Transformer that varies output according to mechanical displacement of coils or cores

INFORMATION SHEET

M. Electrohydraulic control — System in which electronic circuits control valves and cylinders, which in turn control machines and process flows

N. Microprocessor — Electronic computer concentrated into a small electronic component

O. Servomotor — Electrical device that provides power to move system controls

P. Servo system — Automatic control system using electrical signals to represent mechanical settings or operations

(NOTE: A servo system monitors signals through the use of servo receivers and servo transmitters, and compares the readings with predetermined values. The system adjusts mechanical controls to maintain the readings at or near the predetermined values.)

EXAMPLES: A potentiometer that produces an electrical signal based on the level of a float device in a tank may cause a motor to switch on and power a pump to keep the fluid at a certain level.

Q. Limit switch — Mechanically operated switch mounted in the path of a moving object; actuated by the passage of the object

II. Abbreviations associated with remote sensing

A. RTD — Resistive thermal device

B. A/D; adc — Analog-to-digital converter

C. D/A; dac — Digital-to-analog converter

D. Σ — Summing circuit or point

E. XMTR — Transmitter

F. RCVR — Receiver

G. TC — Thermocouple

H. psig — Pounds per square inch, gauge pressure

I. psia — Pounds per square inch, absolute

J. SV — Solenoid valve

K. CV — Control valve

INFORMATION SHEET

L. Op-amp — Operational amplifier

M. TM — Turbine meter

N. LVDT — Linear variable differential transformer

O. XDCR — Transducer

P. gpm — Gallons per minute

Q. ppg — Pulses per gallon

R. EHC — Electrohydraulic control

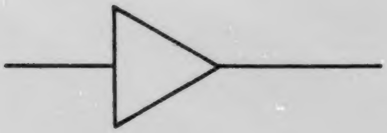
S. cal — Calibration

T. λ — Light

III. Control diagram symbols (Figures 1-19; Assignment Sheet #2)

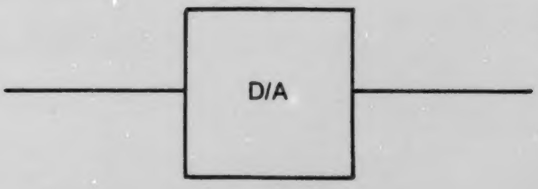
A. Amplifier or buffer

FIGURE 1



B. Digital-to-analog converter

FIGURE 2

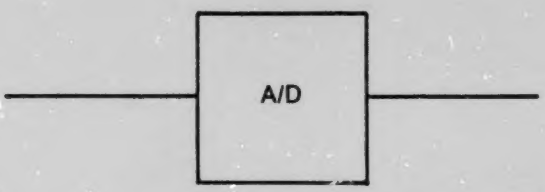


(NOTE: A number of components are represented by a box containing an abbreviation for a particular component.)

INFORMATION SHEET

C. Analog-to-digital converter

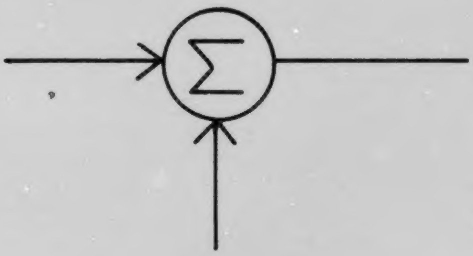
FIGURE 3



D. Summer (summing circuit or point)

(NOTE: A summer may have two or more inputs.)

FIGURE 4



E. Photocells

FIGURE 5

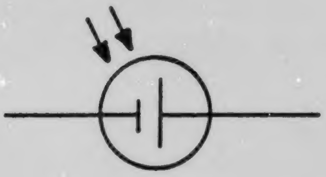
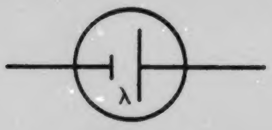


FIGURE 6



INFORMATION SHEET

F. Photoresistors

FIGURE 7

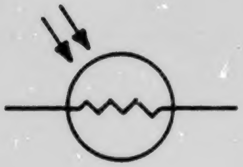
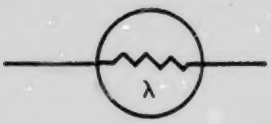
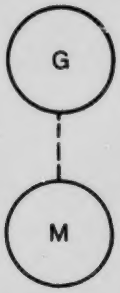


FIGURE 8



G. Motor tachometer generator

FIGURE 9

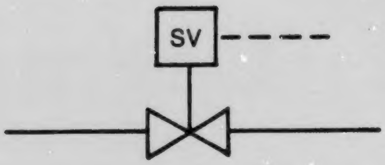


H. Solenoid valve

(NOTE: Process flow lines may be for water, air, hydraulic fluid, etc., and controlled by remote sensing. A solenoid valve only turns off or on.)

EXAMPLE: Water flowing into a tank may be turned off electrically by an automatic control signal generated by a liquid-level switch on the tank.

FIGURE 10

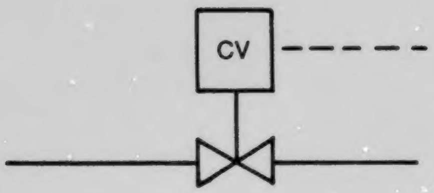


INFORMATION SHEET

I. Control valve

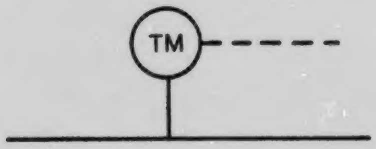
(NOTE: Control valves operate at various stages between open and closed to control flow. Look at the similarity of the solenoid valve and control valve symbols. Typically, control diagram symbols rely on letter abbreviations and include symbols within the blocks.)

FIGURE 11



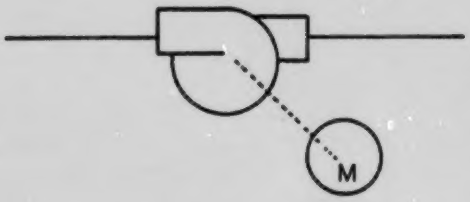
J. Turbine meter

FIGURE 12



K. Pump and motor

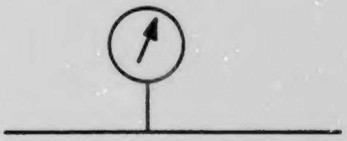
FIGURE 13



INFORMATION SHEET

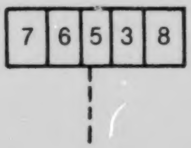
L. Meter or gauge

FIGURE 14



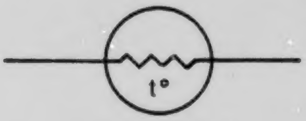
M. Numerical readout

FIGURE 15



N. Thermistor

FIGURE 16



O. Arithmetic circuits

(NOTE: Arithmetic circuits may divide circuits, multiply circuits, or involve complex mathematical operations such as integration or differentiation. The numbers and indications on all control circuitry are important.)

FIGURE 17

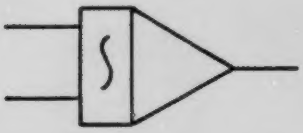
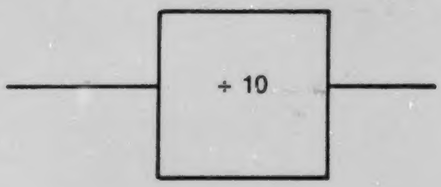


FIGURE 18

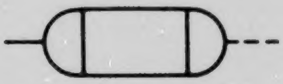


INFORMATION SHEET

P. Servomechanism

(NOTE: The broken line indicates that the servomechanism is positioned with an input signal.)

FIGURE 19



IV. Basic purpose of remote sensing — To measure a parameter and produce a signal that can be transmitted some distance to serve as a monitor or control

EXAMPLE: A wall thermostat is a simple remote sensor. Its purpose is to measure room temperature and send a signal to the building's heating and air-conditioning equipment.

(NOTE: Remote sensing, signal transmitting, and control can be electrical, electronic, pneumatic, hydraulic, or mechanical. It can involve optics and sound and often is a combination of several of these forms. This unit is mainly concerned with electrical and electronic sensing.)

V. Applications for remote sensing

A. Automatic control

EXAMPLE: A temperature sensor in an industrial furnace can control the natural gas valve automatically.

B. Manual control

EXAMPLE: A pressure sensor on a water line can supply a reading to an operator who will turn on an auxiliary pump if the pressure becomes too low.

C. Recording

EXAMPLE: A factory may be required by the Environmental Protection Agency (EPA) to record the readings of waste water discharged into a river as monitored by a distant meter.

INFORMATION SHEET

D. Safety

EXAMPLE: Smoke detectors placed in a warehouse may alert the fire department and may turn on alarms.

E. Security

EXAMPLE: Many industries have intrusion detectors to set off an alarm should an unauthorized entry occur.

VI. Basic components of a remote sensing system (Transparency #1; Assignment Sheet #2)

A. Sensing element (sensor) — Device that senses a change in a parameter, such as temperature or pressure, and outputs a signal as a result

EXAMPLES: Sensor, transducer, detector, pick-up

B. Converter - Device that converts or changes a signal from one type to another

EXAMPLES: Digital-to-analog converter, analog-to-digital converter, circuit that converts from one voltage range to another

C. Transmitter — Device that sends a signal

EXAMPLES: Operational amplifier, driver, buffer amplifier, radio frequency transmitter

D. Transmission medium — Material that serves as path of transmitted signal

EXAMPLES: Signal wire, radio or light waves through air, glass fibers in fiber-optic circuits

E. Receiver — Device that accepts transmitted signal

EXAMPLES: Input amplifier, buffer amplifier

F. Interface — Device that allows one type of circuit or component to work effectively with another type of circuit or component

EXAMPLES: An analog-to-digital converter allows both an analog and a digital circuit to function in a system; an electric motor powering a pump (an electric circuit interfacing with a hydraulic circuit) allows the electrical power to be changed to hydraulic mechanical power.

INFORMATION SHEET

G. Monitor — Device that displays a parameter value

EXAMPLES: Numerical display, totalizer gauge, meter, recorder

H. Controller — Device that reacts to automatic or operator commands and changes a system's operation

EXAMPLES: Solenoid valve, control valve, motor controller

(NOTE: Two or more controllers may be combined in a single circuit. Some systems may not need all of these components.)

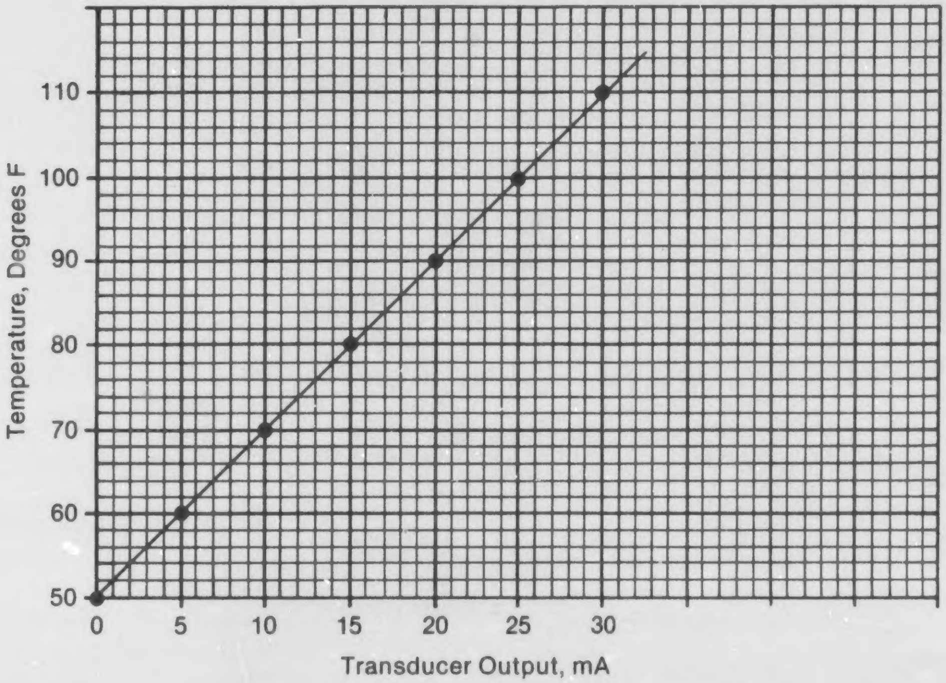
VII. Linear and nonlinear signals

A. Linear (Figure 20; Transparency #2)

(NOTE: Within the operating range of the equipment involved, any change in the parameter being monitored will result in a proportional change in the output of the equipment.)

EXAMPLE: A change in temperature from 60°F to 70°F results in a sensor output change from 5 mA to 10 mA. A change from 90°F to 100°F also results in a 5 mA change in sensor output.

FIGURE 20



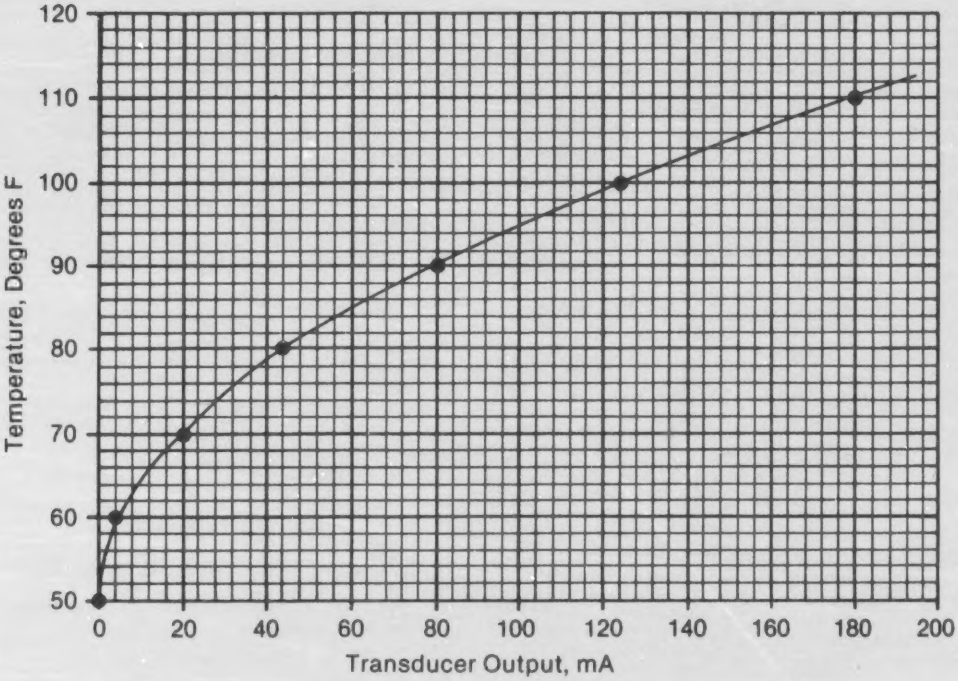
INFORMATION SHEET

B. Nonlinear (Figure 21; Transparency #3)

(NOTE: Along the operating range of the equipment involved, equal changes in the parameter being monitored result in gradually increasing or decreasing changes in the equipment output signal.)

EXAMPLE: A change in temperature from 60°F to 70°F results in a sensor output change from 5 mA to 20 mA. However, a change in temperature from 90°F to 100°F results in a larger change in the output signal from 80 mA to 125 mA.

FIGURE 21

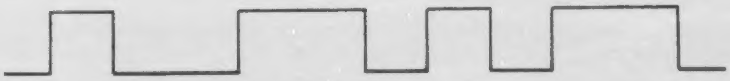


VIII. Types of remote sensing modulation (Figures 22-25)

A. Digital

(NOTE: This signal is shown as it may appear on the oscilloscope. It usually is transmitted as pulsating DC.)

FIGURE 22

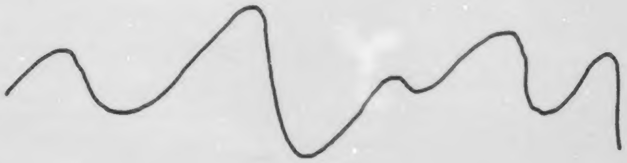


INFORMATION SHEET

B. Analog

(NOTE: This signal is shown as it may appear on a chart recorder. It represents a gradual change in voltage level.)

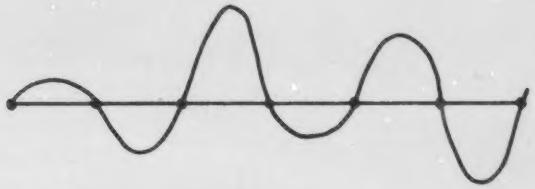
FIGURE 23



C. AC amplitude variable

(NOTE: Only the height of the waveform varies, not the time between peaks.)

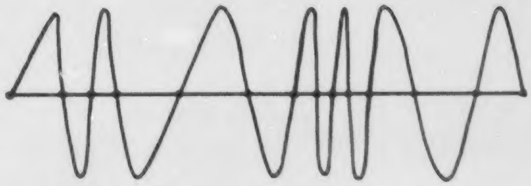
FIGURE 24



D. AC frequency variable

(NOTE: Normally the height does not vary; only the frequency changes.)

FIGURE 25



INFORMATION SHEET

IX. Calculating number of output pulses (Transparency #4; Assignment Sheet #1)

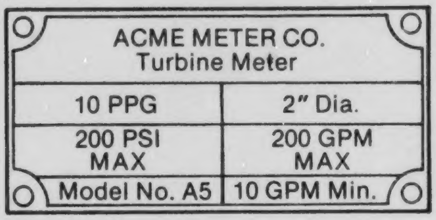
(NOTE: Pulse output rates are useful in checking equipment operation and in calibrating sensors and control equipment.)

A. Determine sensor's pulse rate

(NOTE: Some sensors may be stamped or tagged to show their pulse rate. If not, a technician must refer to the installation blueprints or maintenance manual for the equipment involved, or contact the equipment manufacturer or representative.)

EXAMPLE: A turbine meter that measures fluid flow through a pipe outputs 10 pulses per gallon (ppg) of flow as indicated by the information plate on the instrument (Figure 26).

FIGURE 26



B. Multiply the pulse rate by the rate of the measured parameter

EXAMPLE: The number of pulses per minute for the turbine meter in the example above would be 2000 pulses at the maximum flow rate of 200 gallons per minute.

10 ppg × 200 gallons per minute = 2000 pulses per minute

C. If necessary, convert the pulses per time interval to that used on test equipment

EXAMPLE: A technician would probably use an oscilloscope to monitor the output of the turbine meter in the previous two examples. The technician would be observing the number of pulses per second. To find the pulses per second (pps), divide the pulses per minute (ppm) by 60 (number of seconds per minute).

$$\frac{\text{2000 pulses per minute}}{\text{60 seconds per minute}} = \text{33.4 pulses per second output}$$

INFORMATION SHEET

X. Applications of remote sensing devices

  A. Temperature measurement

    1. Resistive thermal device (RTD)

    2. Thermocouple (TC)

    3. Bimetallic strip attached to potentiometer or variable transformer

  B. Pressure measurement

    1. Pressure transducer

    2. Linear variable differential transformer (LVDT) attached to spring-resistive cylinder or pressure bellows

    3. Potentiometer attached to spring-resistive cylinder or pressure bellows

  C. Fluid flow measurement

    1. Turbine meter

    2. Positive displacement meter connected to digitizer

       (NOTE: A positive displacement meter uses a piston that actually measures the quantity of fluid. It is more accurate than a turbine meter and thus is used for measuring gasoline and diesel fuel at service stations.)

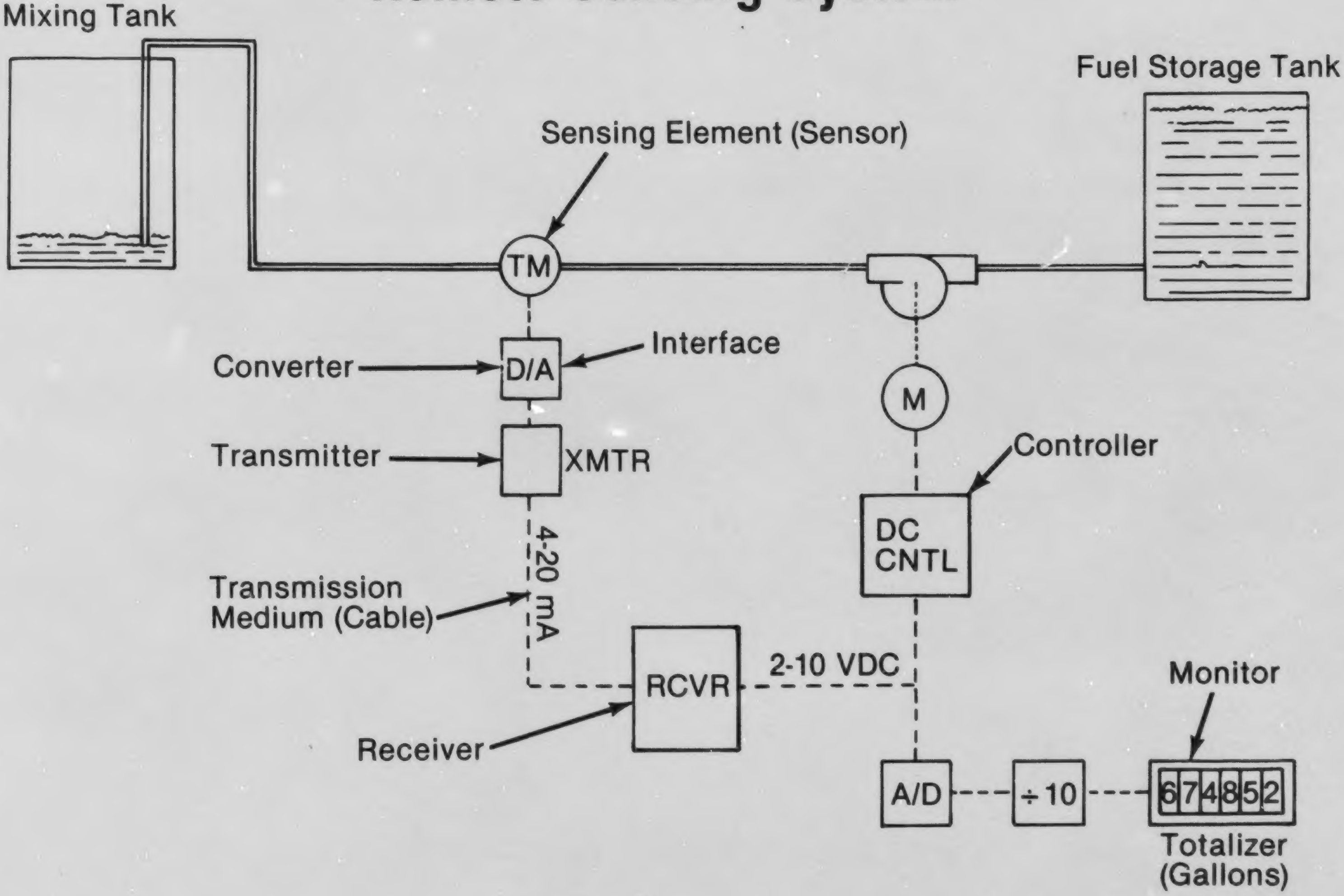
    3. Pitot tube

       (NOTE: Pitot tubes measure the drop in pressure as the fluid flows past an opening.)

    4. Hall-effect devices

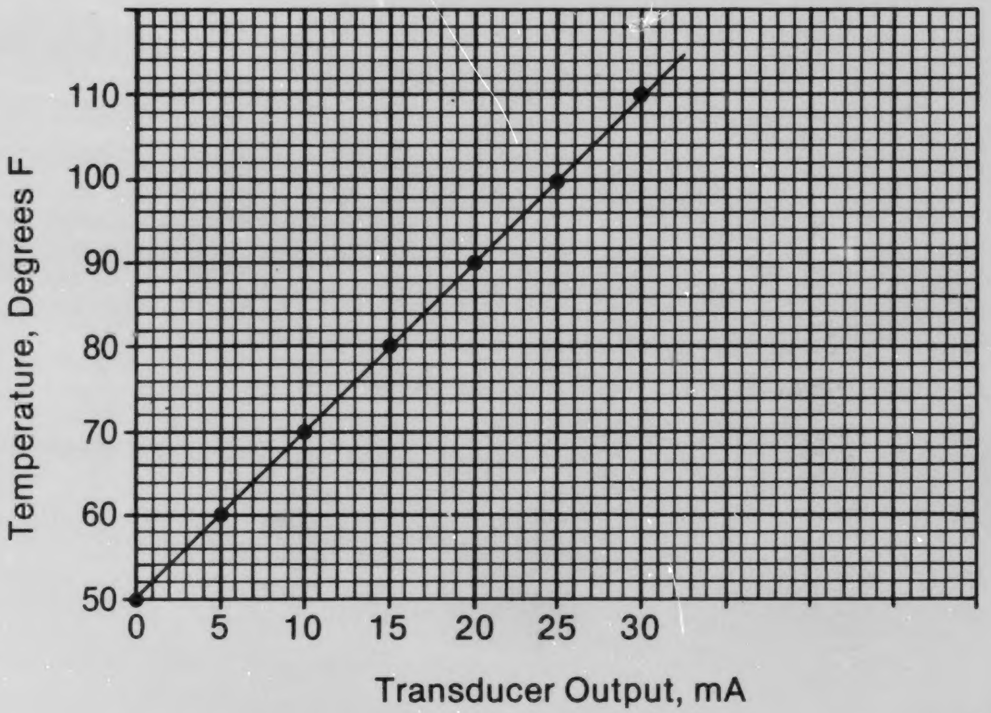
       (NOTE: Hall-effect devices basically consist of semiconductor material conducting current flow with a magnetic field set perpendicular to the current flow. Output voltage runs perpendicular to both the current flow and the magnetic field and is proportional to the product of the current flow times the strength of the magnetic field.)

Remote Sensing System


Mixing Tank
Fuel Storage Tank
Sensing Element (Sensor)
TM
Interface
Converter
D/A
Transmitter
XMTR
4-20 mA
Transmission
Medium (Cable)
RCVR
Receiver
2-10 VDC
M
Controller
DC
CNTL
Monitor
A/D
÷10
674852
Totalizer
(Gallons)

Linear Signal

Graph



Table

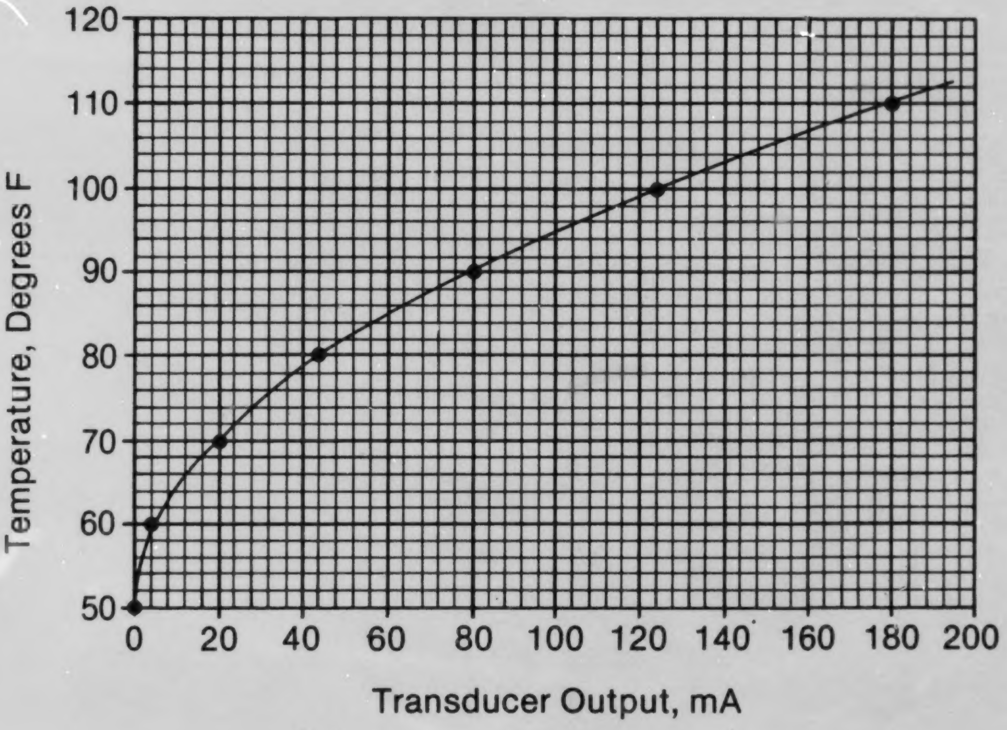
Temperature (°F)	Output (mA)
50	0
60	5
70	10
80	15
90	20
100	25
110	30

TM #2

AIE - 23-A

Nonlinear Signal

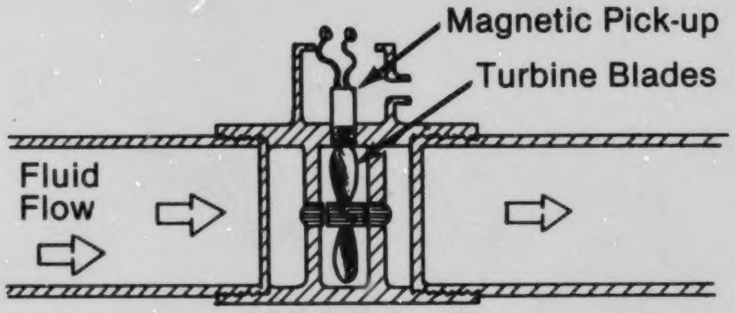
Graph



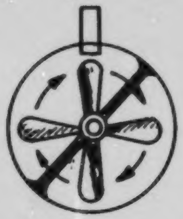
Table

Temperature (°F)	Output (mA)
50	0
60	5
70	20
80	45
90	80
100	125
110	180

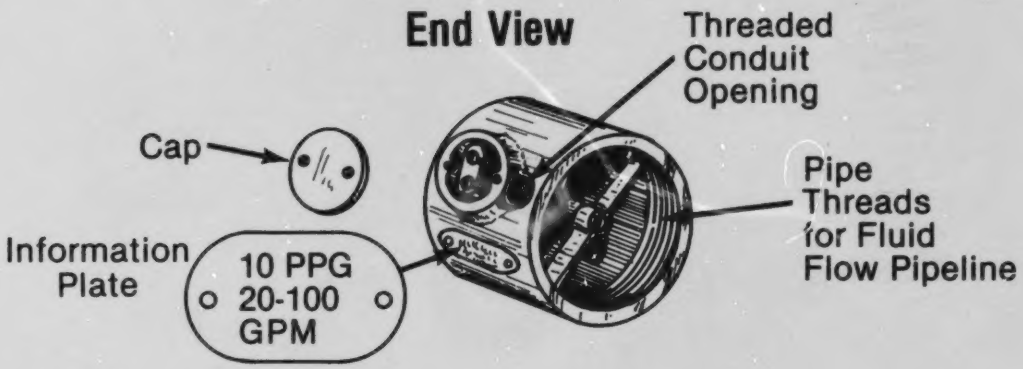
Turbine Meter


Magnetic Pick-up
Turbine Blades
Fluid Flow

Cut-Away Side View



End View


Threaded Conduit Opening
Cap
Pipe Threads for Fluid Flow Pipeline
Information Plate
10 PPG
20-100
GPM

Turbine Meter Table for 10 PPG

Gallons	Pulses
20	200
30	300
40	400
50	500
60	600
70	700
80	800
90	900
100	1000

REMOTE SENSING
UNIT I

ASSIGNMENT SHEET #1 — CALCULATE NUMBER OF OUTPUT PULSES

NAME ____________________ SCORE ____________

Technicians often must know what voltages should be output by the sensor before they can troubleshoot a remote sensing circuit.

Use the steps for calculating output in a linear sensing device in Information Sheet, Section IX, and the information below to complete Tables 1 and 2.

A. A turbine meter in an oil pipeline outputs four pulses per gallon as the oil flows through it and causes it to rotate. Assume that the device is accurate from zero to 50 gpm. How many pulses are there per minute?

TABLE 1

Flow	**Sensor Output**
Gallons per Minute	Pulses per Minute
0	
10	
20	
30	
40	
50	

B. Assume that the meter in problem A had to be calibrated using a monitor that measured the number of impulses per second. What reading would you expect for the following flow rates if the meter is properly calibrated?

TABLE 2

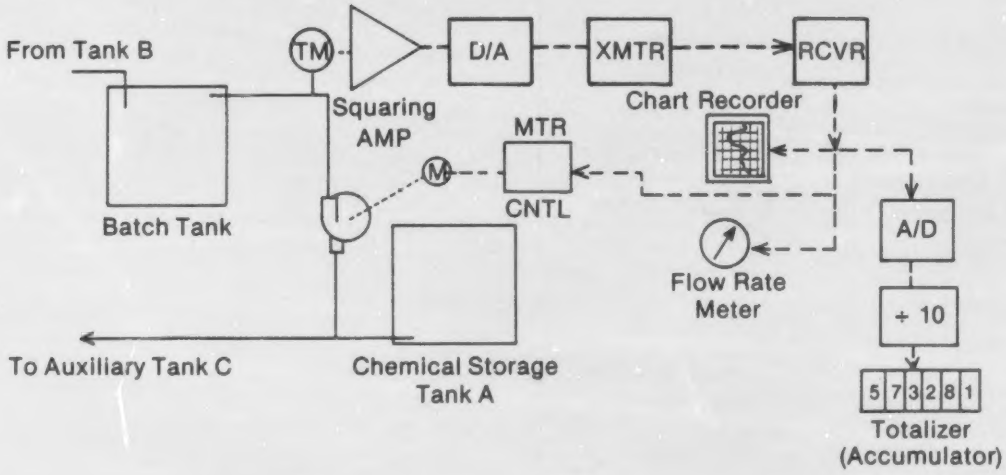
Flow	**Sensor Output**	
Gallons per Minute	Pulses per Minute	Pulses per Second
0		
10		
20		
30		
40		
50		

REMOTE SENSING
UNIT I

ASSIGNMENT SHEET #2 — INTERPRET A FLOW DIAGRAM FOR A REMOTE SENSING CIRCUIT

NAME ______________________________ SCORE ______________

To troubleshoot, calibrate, or repair a control system effectively, a technician must fully understand which functions each element performs. Look at the remote sensing system illustrated and answer the questions or problems that follow. Write your answers in the blanks.


From Tank B
TM
Squaring AMP
D/A
XMTR
RCVR
Chart Recorder
MTR
CNTL
M
Batch Tank
A/D
Flow Rate Meter
÷ 10
To Auxiliary Tank C
Chemical Storage Tank A
5 7 3 2 8 1
Totalizer (Accumulator)

A. Which type of signal is output by the turbine meter?

____

____

B. What function is served by the component between the A/D and the digital display?

____

____

ASSIGNMENT SHEET #2

C. If the turbine meter output is 10 ppg, what will be the input to the totalizer (monitor)?

Input = ______________________________

D. Suppose the range of the turbine meter is 1 gpm to a maximum of 9 gpm. The flow transmitter must be calibrated to output 4 mA at 1 gpm, and 20 mA at 9 gpm. What output should be produced at 5 gpm?

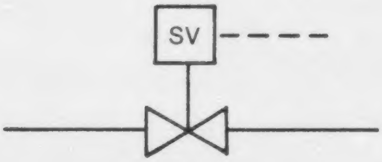
Output = ______________________________

E. Is the transmitter output linear or nonlinear? ______________________________

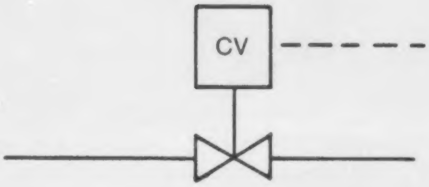
(NOTE: It may help to plot the output versus input.)

ASSIGNMENT SHEET #2

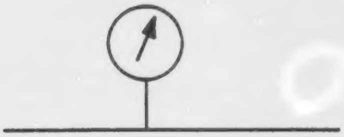
F. Note that the pump is driven by a variable-speed DC motor. If a single-speed motor had been used, which component shown below could have been used to control the rate of flow? Write an "X" in the blank below the correct component.



1. ______________________________



2. ______________________________



3. ______________________________

REMOTE SENSING
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. TABLE 1

Flow	Sensor Output
Gallons per Minute	Pulses per Minute
0	0
10	40
20	80
30	120
40	160
50	200

B. TABLE 2

Flow	Sensor Output	
Gallons per Minute	Pulses per Minute	Pulses per Second
0	0	0
10	40	0.67
20	80	1.33
30	120	2
40	160	2.67
50	200	3.33

Assignment Sheet #2

A. Answer should indicate that it is a frequency-modulated signal. The answer may correctly include other information such as that it is technically a digital signal after the squaring amplifier and that it is probably linear with the range of the device

B. To divide by 10 to reduce the 10 ppg signal to one ppg for the accumulator to show total gallons

ANSWERS TO ASSIGNMENT SHEETS

C. One pulse per gallon

D. 12 mA

E. Linear

F. 2 (control valve)

REMOTE SENSING
UNIT I

JOB SHEET #1 — CONSTRUCT A PHOTOTRANSISTOR REMOTE SENSING CIRCUIT

I. Equipment and materials

- A. Breadboard
- B. Approximately 4 feet of #24 AWG solid tin-copper wire
- C. Operational amplifier integrated circuit, any type 741
- D. Phototransistor, FPT 100
- E. Resistors, ¼ watt, 10 percent
  1. 1 kohm
  2. Two 4.7 kohm
  3. Two 10 kohm
  4. 33 kohm
  5. 15 kohm
- F. Capacitors, 25 volt
  1. 270 microfarad
  2. 10 microfarad
- G. Lamp, #327, with socket, or equivalent 12 V miniature lamp

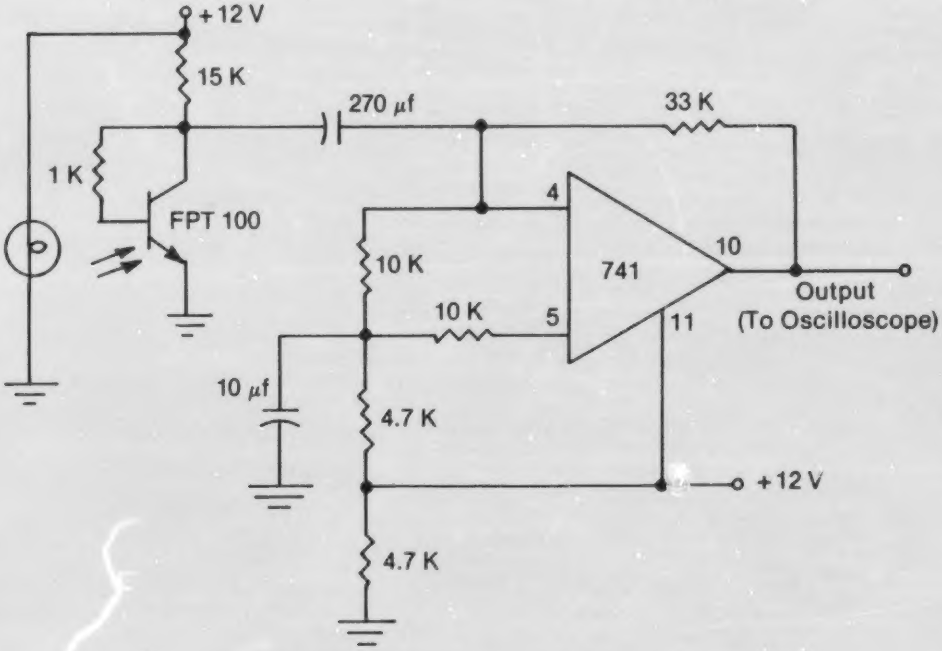
  (NOTE: In place of a socket, two 4-inch (10 cm) lengths of #24 wire may be soldered onto the lamp base. Solder one to the copper base and one to the bottom contact area. Use a minimal amount of solder and heat.)
- H. Oscilloscope
- I. DC power supply or 12-volt battery

JOB SHEET #1

II. Procedure

A. Construct the circuit so that the lamp is less than one inch from the phototransistor (Figure 27)

FIGURE 27


+12 V
15 K
270 μf
33 K
1 K
FPT 100
4
741
10
10 K
10 K
5
11
Output
(To Oscilloscope)
10 μf
4.7 K
+12 V
4.7 K

B. Have instructor check your work

C. Plug in the power supply, but do not connect it to circuit

D. Turn the power supply on

E. Set the output at 12 volts

F. Connect the power supply and the oscilloscope to circuit as indicated

G. Monitor the oscilloscope while covering and uncovering the phototransistor window with your hand

(NOTE: The oscilloscope vertical sensitivity should be approximately 2 volts per centimeter if a 1X probe is used. The trace should move up and down, showing a change in the light detected by the phototransistor.)

JOB SHEET #1

H. Show instructor that circuit operates

I. Turn off power

J. Put away equipment and materials

REMOTE SENSING
UNIT I

JOB SHEET #2 — CONSTRUCT AND TEST A THERMOCOUPLE CIRCUIT

I. Equipment and materials

   A. Thermocouple wire pair (iron and Constantan, Chromel and Alumel, or copper and Constantan), approximately 3 feet in length

   B. Source of heat such as a small propane torch, laboratory burner, or propane lighter

   C. Millivolt meter, digital or conventional

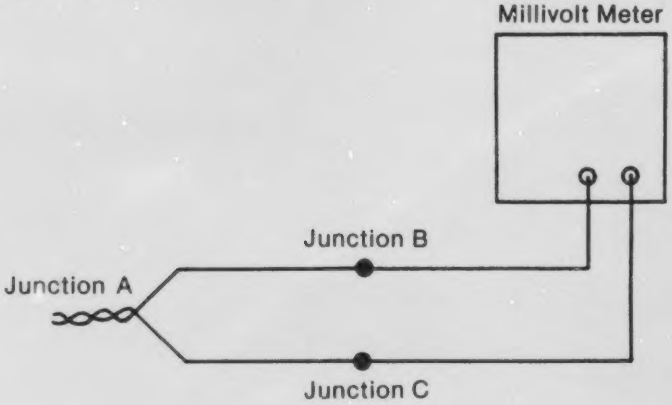
II. Procedure

   A. Strip approximately 3 inches of the protective covering from ends of thermocouple wire

   B. Twist the ends of the thermocouple pair (Junction A) together tightly at one end (Figure 28)

   (NOTE: For a permanent industrial installation, the twisted ends would be soldered with a high-temperature solder able to withstand the temperature being measured.)

FIGURE 28



   C. Connect the untwisted ends to the millivolt meter leads

   (CAUTION: To ensure proper conductivity, do not use alligator clips with insulators at junctions B and C.)

JOB SHEET #2

D. Record the millivolt reading at room temperature

(NOTE: Observe the polarity and show it as positive [+] or negative [−] with the numbers you record.)

Room temperature = ____________________millivolts

E. Heat junction A slightly and watch the millivolt meter; record the highest reading

Slight heating = ____________________millivolts

F. Heat junction A to a higher temperature; record the reading

Moderate heating = ____________________millivolts

G. Cool junction A with a cup of water; record the reading

Water-cooled = ____________________millivolts

H. Leave junction A in a cup of water to stabilize its temperature

I. Slightly heat each one of the "cold junction" leads (junctions B and C); record the readings

Cold junction B = ____________________millivolts

Cold junction C = ____________________millivolts

(NOTE: Show readings to your instructor, and ask why this effect occurred.)

J. Put away equipment and materials

REMOTE SENSING
UNIT I

JOB SHEET #3 — CONSTRUCT AND TEST A DIGITAL-TO-ANALOG CONVERTER CIRCUIT

I. Equipment and materials needed

   A. Breadboard

   B. #22 AWG solid copper insulated wire

   C. Integrated circuit digital-to-analog converter: Sprague type UM-1504, or equivalent D/A DIP integrated circuit for four to eight inputs

   D. Resistor: 1/4 watt, 4.7 kohm

   E. Four to eight miniature single pole, double throw (SPDT) switches, according to number of inputs available on the integrated circuit used

   F. Potentiometer, miniature, 10 kohm

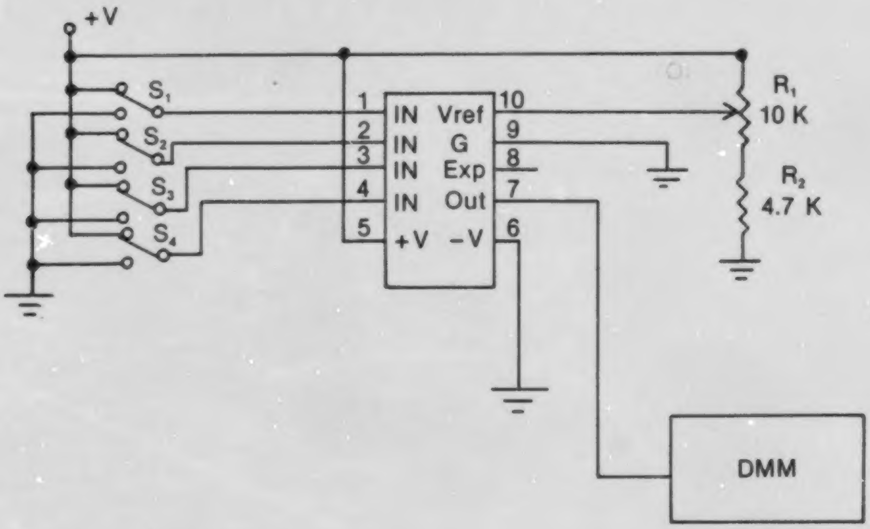
   G. Digital voltmeter

   H. DC power supply, regulated

II. Procedure

   A. Construct the circuit shown in Figure 29

FIGURE 29



JOB SHEET #3

B. Show your instructor the finished circuit

C. Consult manufacturer's reference to determine the proper voltage for the integrated circuit used; if none is available, set the power supply to 12 volts

D. Place all switches so that a ground is connected to the integrated circuit inputs

E. Observe the voltage output; adjust the potentiometer for an even reading

F. Record the reading in Table 3

G. Reset switches to the next setting and record the reading; continue until a reading of voltage output has been made for all settings shown in Table 3

TABLE 3

Switch Positions				**Reading**
S1	S2	S3	S4	(Analog)
Off	Off	Off	Off	
Off	Off	Off	On	
Off	Off	On	Off	
Off	On	Off	Off	
Off	On	On	Off	
On	Off	Off	Off	
On	Off	On	Off	
On	On	Off	Off	
On	On	On	Off	
On	On	On	On	

H. Show your results to the instructor

I. Put away equipment and materials

REMOTE SENSING
UNIT I

TEST

NAME ______________________________________ SCORE ________________

1. Match terms associated with remote sensing circuits to their correct definitions. Write the correct numbers in the blanks. Terms and definitions are continued on next page.

_____a. Instrument adjustment so that a specific input produces a required output over the intended operating range

_____b. Automatic control system using electrical signals to represent mechanical settings or operations

_____c. Mechanically operated switch mounted in the path of a moving object; actuated by the passage of the object

_____d. Electrical device that provides power to move system controls

_____e. Electronic computer concentrated into a small electronic component

_____f. Transformer that varies output according to mechanical displacement of coils or cores

_____g. System in which electronic circuits control valves and cylinders, which in turn control machines and process flows

_____h. Instrument's ability to measure the actual or theoretical value of a parameter

_____i. Instrument's ability to produce measurable changes in outputs as a result of measurable changes in inputs

_____j. Device that converts energy from one form to another at known and consistent rates

_____k. Generator attached to a rotating machine in order to monitor rotational speed

_____l. Electrically operated valve that opens or closes to control fluid or gas flow through pipes

_____m. Rotating blades that produce an electronic signal that represents the quantity of fluid or gas flow through pipes

1. Accuracy
2. Calibration
3. Resolution
4. Servomotor
5. Transducer
6. Servo system
7. Electrohydraulic control
8. Limit switch
9. Microprocessor
10. Linear variable differential transformer
11. Motor tachometer generator
12. Solenoid valve
13. Turbine meter

TEST

_____n. Resistors that vary with temperature and are used as temperature sensors

_____o. Electronic device that combines two or more analog signals into a single output

_____p. Temperature-sensing device made of the junction of two dissimilar metals that produce a small voltage related to the ambient temperature at junction

_____q. Valve that can be at various stages between open and closed to adjust the fluid or gas flow through pipes

14. Control valve
15. Thermocouple
16. Resistive thermal devices
17. Summing circuit

2. Match abbreviations associated with remote sensing to their correct definitions. Write the correct numbers in the blanks.

_____a. Analog-to-digital converter

_____b. Calibration

_____c. Operational amplifier

_____d. Resistive thermal device

_____e. Summing circuit or point

_____f. Pounds per square inch, absolute

_____g. Solenoid valve

_____h. Pulses per gallon

_____i. Gallons per minute

_____j. Transducer

_____k. Turbine meter

_____l. Electrohydraulic control

_____m. Digital-to-analog converter

_____n. Transmitter

_____o. Pounds per square inch, gauge pressure

_____p. Receiver

_____q. Thermocouple

_____r. Linear variable differential transformer

_____s. Control valve

_____t. Light

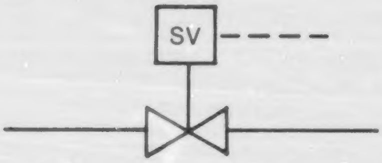
1. RTD
2. A/D; adc
3. D/A; dac
4. Σ
5. XMTR
6. RCVR
7. TC
8. psig
9. psia
10. SV
11. CV
12. Op-amp
13. TM
14. LVDT
15. XDCR
16. gpm
17. ppg
18. EHC
19. cal
20. λ

TEST

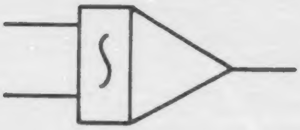
3. Identify the control diagram symbols shown in the following illustrations. Write the correct names in the blanks.

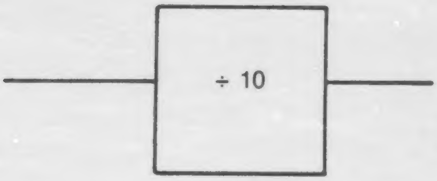
Control valve
Solenoid valve
Photoresistors
Arithmetic circuits
Amplifier or buffer
Pump and motor
Meter or gauge
Digital-to-analog converter

Analog-to-digital converter
Thermistor
Summer (summing circuit or point)
Motor tachometer generator
Turbine meter
Numerical readout
Photocells
Servomechanism

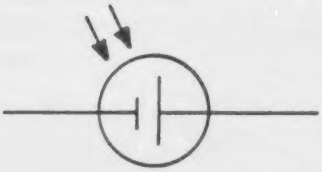


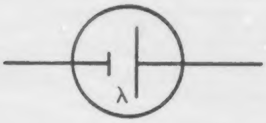
a. ______________________________





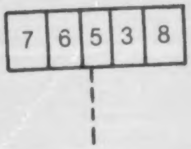
b. ______________________________



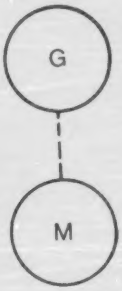


c. ______________________________

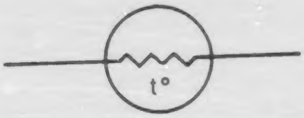
TEST



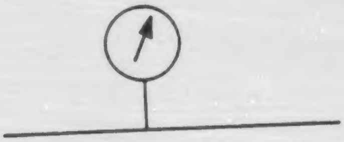
d. ______________________________



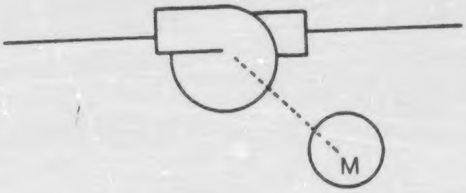
e. ______________________________



f. ______________________________

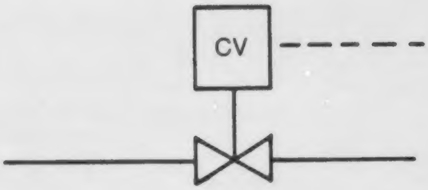


g. ______________________________

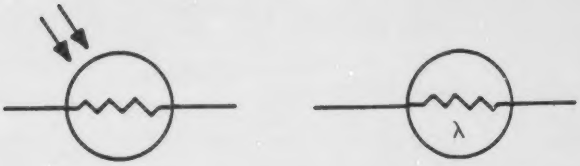


h. ______________________________

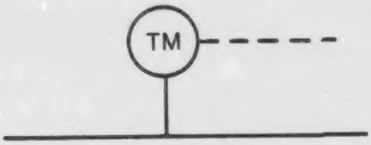
TEST



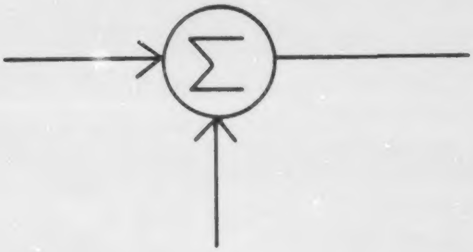
i. ______________________________



j. ______________________________

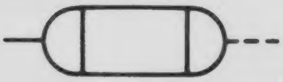


k. ______________________________

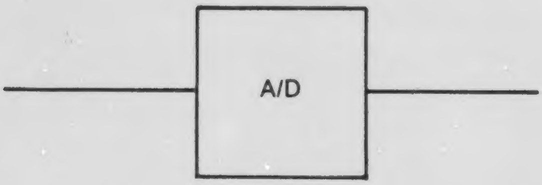


l. ______________________________

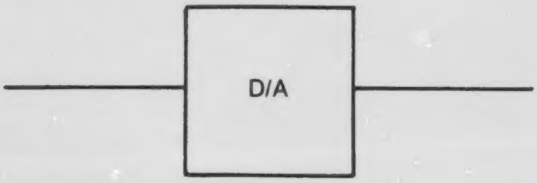
TEST



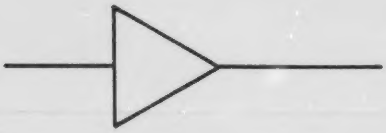
m. ______________________________



n. ______________________________



o. ______________________________



p. ______________________________

TEST

4. State the basic purpose of remote sensing.

____

____

5. List applications for remote sensing.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

6. Match the basic components of a remote sensing system to their correct descriptions. Write the correct numbers in the blanks.

______a. Device that sends a signal

______b. Device that accepts transmitted signal

______c. Device that senses a change in a parameter, such as temperature or pressure, and outputs a signal as a result

______d. Device that converts or changes a signal from one type to another

______e. Material that serves as path of transmitted signal

______f. Device that allows one type of circuit or component to work effectively with another type of circuit or component

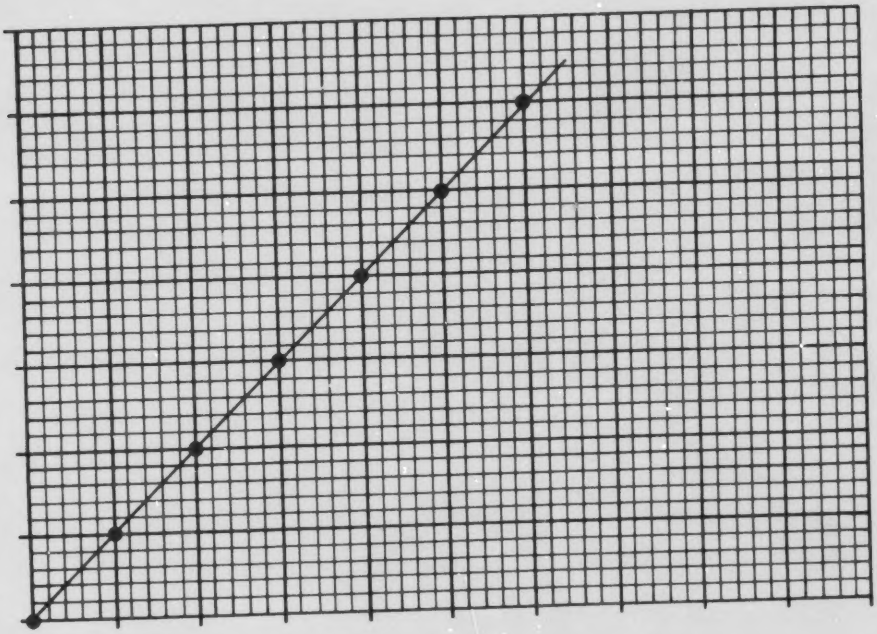
______g. Device that displays a parameter value

______h. Device that reacts to automatic or operator commands and changes a system's operation

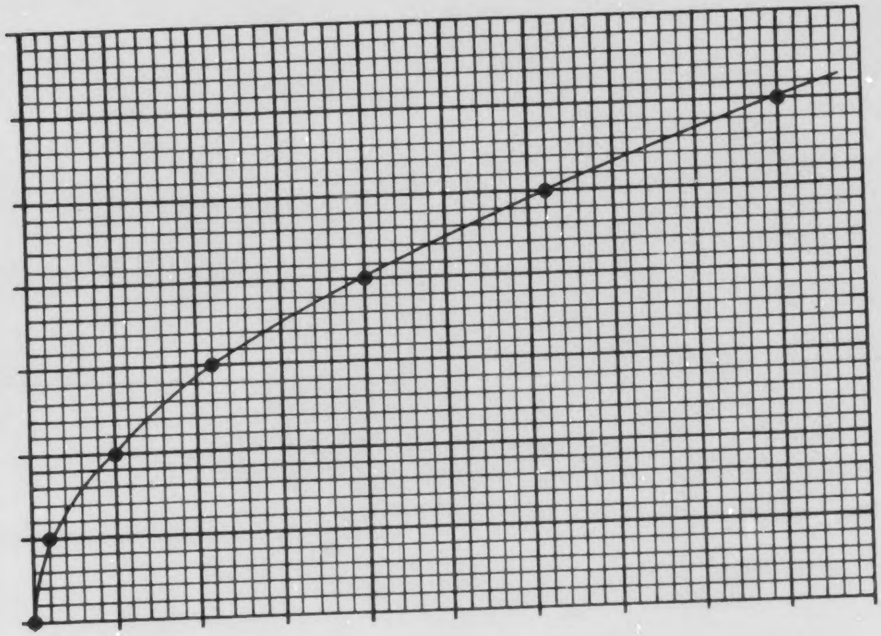
1. Controller
2. Converter
3. Interface
4. Monitor
5. Receiver
6. Sensing element (sensor)
7. Transmission medium
8. Transmitter

7. Label linear and nonlinear signals represented on the following graphs. Write the correct names in the blanks.

TEST



a. ______________________________

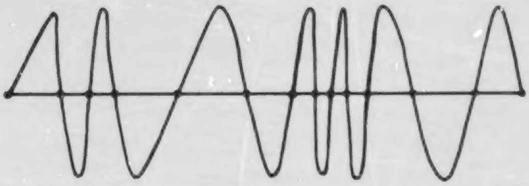


b. ______________________________

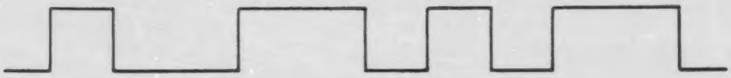
TEST

8. Identify types of remote sensing modulation shown in the following illustrations. Write the correct names in the blanks.

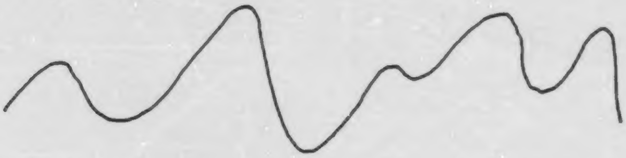
Digital
Analog
AC amplitude variable
AC frequency variable



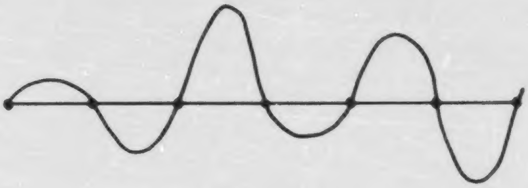
a. ______________________________



b. ______________________________



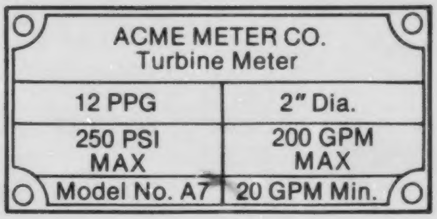
c. ______________________________



d. ______________________________

TEST

9. Calculate number of output pulses. Use the turbine meter label below and the formulas for calculating output pulses to answer the questions.



ACME METER CO.
Turbine Meter

12 PPG	2" Dia.
250 PSI MAX	200 GPM MAX
Model No. A7	20 GPM Min.

a. What is the number of output pulses per second at 100 gpm? ____________

b. What is the number of output pulses per second at 150 gpm? ____________

10. Identify applications of remote sensing devices. Write a "T" before those devices used for temperature measurement, a "F" before those used for fluid flow measurement, and a "P" before those used for pressure measurement.

_____a. Pressure transducer

_____b. Potentiometer attached to spring-resistive cylinder or pressure bellows

_____c. Hall-effect devices

_____d. Turbine meter

_____e. Linear variable differential transformer (LVDT) attached to spring-resistive cylinder or pressure bellows

TEST

_____f. Thermocouple (TC)

_____g. Resistive thermal device (RTD)

_____h. Pitot tube

_____i. Positive displacement meter connected to digitizer

_____j. Bimetallic strip attached to potentiometer or variable transformer

(NOTE: Test questions 11 and 12 list assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

11. Interpret a flow diagram for a remote sensing circuit.

12. Demonstrate the ability to

    a. Construct a phototransistor remote sensing circuit.

    b. Construct and test a thermocouple circuit.

    c. Construct and test a digital-to-analog converter circuit.

REMOTE SENSING
UNIT I

ANSWERS TO TEST

1.	a.	2	f.	10	j.	5	n.	16
	b.	6	g.	7	k.	11	o.	17
	c.	8	h.	1	l.	12	p.	15
	d.	4	i.	3	m.	13	q.	14
	e.	9						

2.	a.	2	f.	9	k.	13	p.	6
	b.	19	g.	10	l.	18	q.	7
	c.	12	h.	17	m.	3	r.	14
	d.	1	i.	16	n.	5	s.	11
	e.	4	j.	15	o.	8	t.	20

3.	a.	Solenoid valve	i.	Control valve
	b.	Arithmetic circuits	j.	Photoresistors
	c.	Photocells	k.	Turbine meter
	d.	Numerical readout	l.	Summer (summing circuit or point)
	e.	Motor tachometer generator	m.	Servomechanism
	f.	Thermistor	n.	Analog-to-digital converter
	g.	Meter or gauge	o.	Digital-to-analog converter
	h.	Pump and motor	p.	Amplifier or buffer

4. To measure a parameter and produce a signal that can be transmitted some distance to serve as a monitor or control

5. a. Automatic control

   b. Manual control

ANSWERS TO TEST

c. Recording
d. Safety
e. Security

6. a. 8 e. 7
b. 5 f. 3
c. 6 g. 4
d. 2 h. 1

7. a. Linear signal
b. Nonlinear signal

8. a. AC frequency variable
b. Digital
c. Analog
d. AC amplitude variable

9. a. 16.67 pulses per second
b. 25 pulses per second

10. a. P f. T
b. P g. T
c. F h. F
d. F i. F
e. P j. T

11. Evaluated to the satisfaction of the instructor

12. Performance skills evaluated to the satisfaction of the instructor

INDUSTRIAL USES OF TRANSDUCERS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to select the proper transducers for specific applications and to state methods for testing and calibrating transducers for industrial uses. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with transducers to their correct definitions.
2. Match abbreviations and symbols associated with transducers to their correct interpretations.
3. Identify circuit and diagram symbols associated with transducers.
4. Classify transducers according to their outputs.
5. State general methods for testing or calibrating a transducer.
6. List parameters monitored by transducers in industrial use.
7. List industrial applications of transducers used as detectors.
8. Match to their correct functions agencies concerned with industrial detection systems.
9. Select the proper transducers for specific applications.
10. Select the proper test equipment for various transducers.
11. Demonstrate the ability to
    a. Analyze a phototransistor light-detector circuit.
    b. Analyze the output of a pressure transducer.
    c. Construct and test a variable-transformer transducer.
    d. Construct and test a Hall-effect sensor circuit.

INDUSTRIAL USES OF TRANSDUCERS
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Make transparencies.

  B. Schedule a field trip to a local industry to see transducer systems, including remote sensing circuits, transmitters, and controls.

  C. Collect various types of transducers to show students. Ask local industries to donate transducers. They may have some that are surplus or are no longer used in their application. Defective transducers from industry can be used to show various types.

  D. Provide students with objective sheet.

  E. Discuss unit and specific objectives.

  F. Provide students with information sheet, assignment sheets, and job sheets.

  G. Discuss information sheet.

  H. Set up a type of pressure transducer to an air line with an adjustable regulator. Show the students how output varies with varying pressures.

  I. Construct a photocell detector and place it by the classroom door, having it turn on a light or buzzer as people walk through the door.

  J. Demonstrate the temperature detection operation of an RTD or thermistor, using a soldering iron or heat gun and a simple battery circuit in series to an oscilloscope.

  K. Demonstrate and discuss assignment sheets and job sheets.

  L. Give test.

II. Instructional materials

  A. Objective sheet

  B. Suggested activities

  C. Information sheet

SUGGESTED ACTIVITIES

D. Transparency masters

  1. TM #1 — Testing or Calibrating a Pressure Transducer System
  2. TM #2 — Testing or Calibrating a Temperature Transducer System
  3. TM #3 — Testing or Calibrating a Chemical Detector Transducer System

E. Assignment sheets

  1. Assignment Sheet #1 — Select the Proper Transducers for Specific Applications
  2. Assignment Sheet #2 — Select the Proper Test Equipment for Various Transducers

F. Answers to assignment sheets

G. Job sheets

  1. Job Sheet #1 — Analyze a Phototransistor Light-Detector Circuit
  2. Job Sheet #2 — Analyze the Output of a Pressure Transducer
  3. Job Sheet #3 — Construct and Test a Variable-Transformer Transducer
  4. Job Sheet #4 — Construct and Test a Hall-Effect Sensor Circuit

H. Test

I. Answers to test

III. Unit references

A. Chanlett, Emil T. *Environmental Protection.* New York: McGraw-Hill, 1973.

B. Cooper, William David. *Electronic Instrumentation and Measurement Techniques.* Englewood Cliffs, New Jersey: Prentice-Hall, 1970.

C. *Instrumentation and Controls.* Waco, Texas: Center for Occupational Research and Development, 1981.

D. *Omega 1980 Temperature Measurement Handbook.* Stanford, Connecticut: Omega Engineering, Inc., 1980.

SUGGESTED ACTIVITIES

E. *Plant Engineering Directory and Specifications Catalog*. Barrington, Illinois: Technical Publishing, 1981.

F. Robertson, Paul L., and George S. Amsbary. *Basic Electronics II: A Curriculum Manual.* Santa Fe: The Vocational-Technical Division of the New Mexico State Department of Education, 1974.

G. Spector, Leo, ed. *Plant Engineering Directory and Specifications Catalog.* Barrington, Illinois: Technical Publishing, 1981.

H. Teague, Cash, and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1984.

INDUSTRIAL USES OF TRANSDUCERS
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Transducer — Device that converts energy from one form to another at a known rate; may be used as a sensor

(NOTE: The terms *detector, sensor,* or *transducer* are often used interchangeably and are only slightly different in definition.)

B. Parameters — Any of the physical properties that constitute the environment

EXAMPLES: Heat, light, humidity, pressure

C. Photoresistive — Changing resistance as a result of light exposure

D. Photoemissive — Releasing electrons as a result of light exposure

E. Photoconductive — Conducting electricity at various levels depending upon amount of light exposure; similar to photoresistive

(NOTE: Conductance may also be associated with active devices such as phototransistors, photodiodes, and phototubes.)

F. Photovoltaic — Generating voltage output as a result of light exposure

G. Strain gauge — Device that can be attached to mechnical parts to measure slight bending, crushing, or stretching

EXAMPLE: A strain gauge attached to a beam on a bridge and connected to an electronic circuit measures the strain of the beam as traffic crosses the bridge.

H. Turbine meter — Device for measuring flow by measuring the rotation of a fan or turbine as the flow rotates it

EXAMPLE: Wind velocity turbine

I. Positive displacement meter — Device that measures flow by the rate and number of piston movements necessary to pump the fluid

EXAMPLE: Ordinary service station gasoline pump

J. Electromagnetic fluid-flow detector — Device that measures fluid flow in a pipe by detecting the disruption of magnetic forces passing across the flow path

INFORMATION SHEET

K. Chemical cell — Transducer whose voltage output varies in reaction to a particular chemical

L. Accelerometer — Device made from permanent magnet, strain gauge, or crystal; used to measure the acceleration and amplitude of vibration

(NOTE: Accelerometers are used to detect abnormal vibrations in machinery.)

M. Turbidity meter — Device used to measure amount of impurities in a liquid by passing a light beam through the liquid

N. Opacity meter — Device used to measure the density of gases, particularly smokestack gases, by passing a light beam through the gases

O. Thermocouple — Junction of two dissimilar metals that produces a small voltage when heated; voltage varies according to temperature

P. Bimetal strip — Strip formed of two dissimilar metals with different heat expansion properties that cause bending to occur when heat varies

II. Abbreviations and symbols associated with transducers

A. XTL — Crystal

B. XDCR — Transducer

C. λ — Light

D. UV — Ultraviolet

E. IR — Infrared

F. Δ — Change in

EXAMPLES: ΔP, change in pressure
Δf, change in frequency
Δv, change in voltage

G. Mic — Microphone

H. XFMR — Transformer

I. ↙↙ — Light rays or other electromagnetic radiation

J. t° — Temperature effect

K. PT — Pressure transmitter

INFORMATION SHEET

L. FT — Flow transmitter

M. RTD — Resistive thermal device

N. TC — Thermocouple

O. psi — Pounds per square inch

P. psia — Pounds per square inch, absolute

Q. psig — Pounds per square inch, gauge

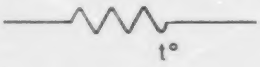
R. XMTR — Transmitter

S. pH — Parts of hydrogen (acidity measured as positive ions)

III. Circuit and diagram symbols associated with transducers (Figures 1-26)

A. Thermistor

FIGURE 1



B. Photoresistor (photoconductive cell)

FIGURE 2

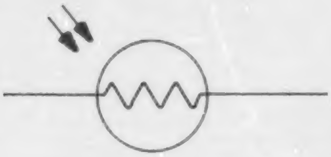
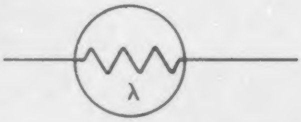


FIGURE 3



INFORMATION SHEET

C. Photocell (photovoltaic cell)

FIGURE 4

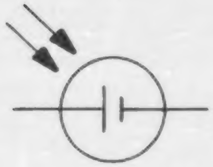
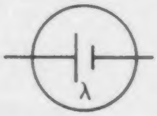
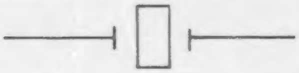


FIGURE 5



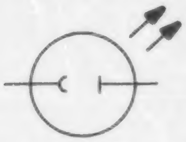
D. Crystal

FIGURE 6



E. Phototube (photoemissive cell)

FIGURE 7



F. Thermocouple

FIGURE 8

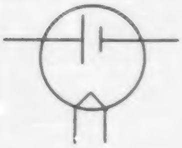
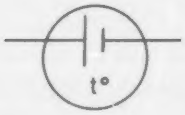


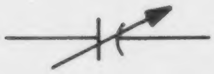
FIGURE 9



INFORMATION SHEET

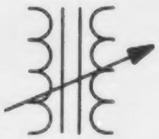
G. Variable capacitor

FIGURE 10



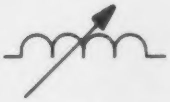
H. Variable transformer

FIGURE 11



I. Variable inductor

FIGURE 12



J. Variable resistor

FIGURE 13

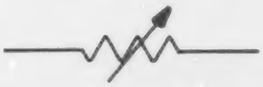
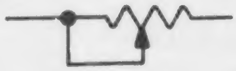


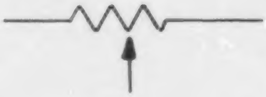
FIGURE 14



INFORMATION SHEET

K. Potentiometer

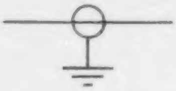
FIGURE 15



L. Grounded, shielded wire

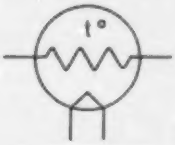
(NOTE: This is the equivalent to the oscilloscope concentric axial cable.)

FIGURE 16



M. RTD with independent integral heater

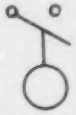
FIGURE 17



INFORMATION SHEET

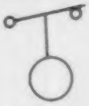
N. Liquid-level switches

FIGURE 18



High Level Closes

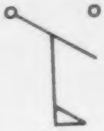
FIGURE 19



High Level Opens

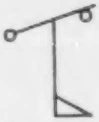
O. Flow switches

FIGURE 20



Flow Closes

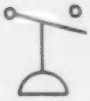
FIGURE 21



Flow Opens

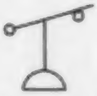
P. Pressure switches

FIGURE 22



Pressure Closes

FIGURE 23

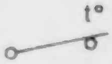


Pressure Opens

INFORMATION SHEET

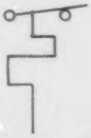
Q. Temperature switches

FIGURE 24



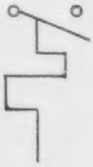
Heat Opens

FIGURE 25



Heat Opens

FIGURE 26



Heat Closes

IV. Output classifications of transducers (Assignment Sheet #2)

A. Variable resistance

1. Thermistor
2. Resistive thermal device
3. Photoresistor
4. Potentiometer

B. Variable voltage output

1. Strain gauge
2. Photovoltaic cell
3. Thermocouple
4. Piezoelectric crystal
5. Variable transformer
6. Chemical cell

C. Variable frequency

1. Piezoelectric crystal
2. Accelerometer

INFORMATION SHEET

D. Variable emission

1. Phototube

   (NOTE: Phototubes are vacuum tubes that react to light exposure.)

2. Phototransistor

3. Photodiode

   (NOTE: Phototransistors and photodiodes are solid-state semiconductors that react to light.)

4. Ionic particle detector

   (NOTE: Ionic particle detectors react to particles created by fire.)

V. General methods for testing or calibrating a transducer

A. Compare operation to a second measuring device (Transparencies #1 and #2)

B. Compare operation with known conditions (Transparency #3)

VI. Parameters monitored by transducers in industrial use

A. Chemicals

EXAMPLE: Hazardous chemicals in waste water

B. Temperature

EXAMPLE: Temperatures in furnaces and boilers

C. Radioactivity

EXAMPLE: Radioactivity from leaks in nuclear reactors

D. Humidity

EXAMPLE: Humidity in environment of large computers

E. Vibration

EXAMPLE: Vibration in an operating machine

F. Visible light

EXAMPLE: Light passed through a clear liquid to detect impurities

INFORMATION SHEET

G. Infrared light

EXAMPLE: Infrared light from a flame in a furnace burner

H. Ultraviolet light

EXAMPLE: Ultraviolet light produced by the combustion of certain fuels

I. Audible sound

EXAMPLES: Unsafe noise levels, sounds of unauthorized entry, malfunctioning machine noise

J. Ultrasonics

EXAMPLE: Ultrasonic vibrations used to inspect metal parts for internal flaws

K. Fluid or gas flow

EXAMPLES: Wind speed; combustion (burner) airflow; ventilation, heating, and air conditioning airflow

(NOTE: Airflow is measured by a combination of pressure and velocity.)

L. Pressure

EXAMPLES: Gas, steam, atmospheric pressures

M. Liquid level

EXAMPLE: Level of liquids in storage tanks

VII. Industrial applications of transducers used as detectors

A. Fire protection

EXAMPLES: Heat switches, smoke detectors, explosive gas sensors

B. Security

EXAMPLES: Sound detectors, motion detectors, photocells

C. Traffic control

EXAMPLES: Traffic lights or automatic gates using electromagnetic or pressure transducers to detect vehicles

INFORMATION SHEET

D. Pollution detection and control

EXAMPLES: Smoke detectors on industrial smokestack, chemical detectors in wastewater channels

E. Personnel protection

EXAMPLES: Noise level monitors, radiation or poisonous gas detectors

F. Process control

EXAMPLES: Measurements of temperature, flow, or concentration of fluids or gases

G. Nondestructive testing (NDT)

EXAMPLES: X rays of pipeline welds, ultrasonic tests of material uniformity, strain gauge tests on structures

VIII. Agencies concerned with industrial detection systems

(NOTE: There are numerous federal, state, and local agencies that may set standards for detection systems. There are also numerous private and professional agencies that establish specifications, perform testing, and make recommendations. A few of the more important agencies are cited here.)

A. Occupational Safety and Health Act (OSHA) — Prescribes and regulates protection, and monitors conditions that may affect workers' health and safety

B. Environmental Protection Agency (EPA) — Regulates the control and disposal of hazardous industrial products and waste materials

C. National Fire Protection Association (NFPA) — Prescribes codes for electrical equipment and wiring, including fire protection and detection systems; publishes the *National Electrical Code* (*NEC*)

D. Nuclear Regulatory Commission (NRC) — Regulates radioactive materials, devices, and industries

E. American Society of Mechanical Engineers (ASME) — Prescribes codes for pressure vessels, testing procedures, and so forth

F. Institute of Electrical and Electronics Engineers (IEEE) — Specifies standards for electrical and electronic equipment

G. Underwriters' Laboratory (UL) — Tests and approves electrical equipment for safety and effectiveness

INFORMATION SHEET

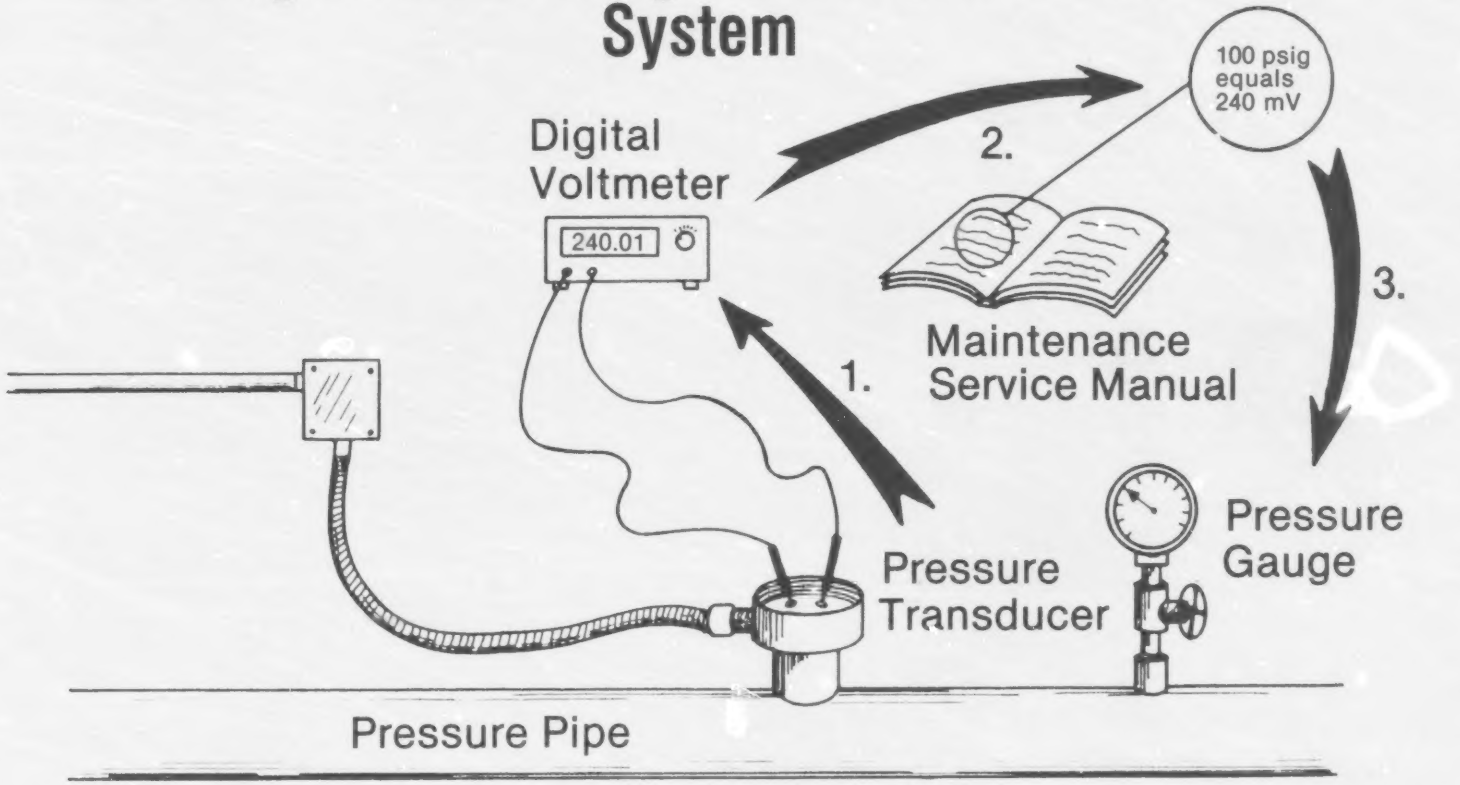
H. Federal Communications Commission (FCC) — Regulates communications equipment and radio-frequency transmitting equipment

I. National Bureau of Standards (NBS) — Sets standards for testing and measurement in the United States

J. Canadian Standards Association (CSA) — Canadian equivalent of the NBS

(NOTE: Due to rapid technological growth and the large number of companies with facilities in both the United States and Canada, both NBS and CSA standards may apply to the design, operation, and limitations of electronic systems.)

Testing or Calibrating a Pressure Transducer System


100 psig
equals
240 mV
Digital
Voltmeter
240.01
2.
3.
Maintenance
Service Manual
1.
Pressure
Gauge
Pressure
Transducer
Pressure Pipe

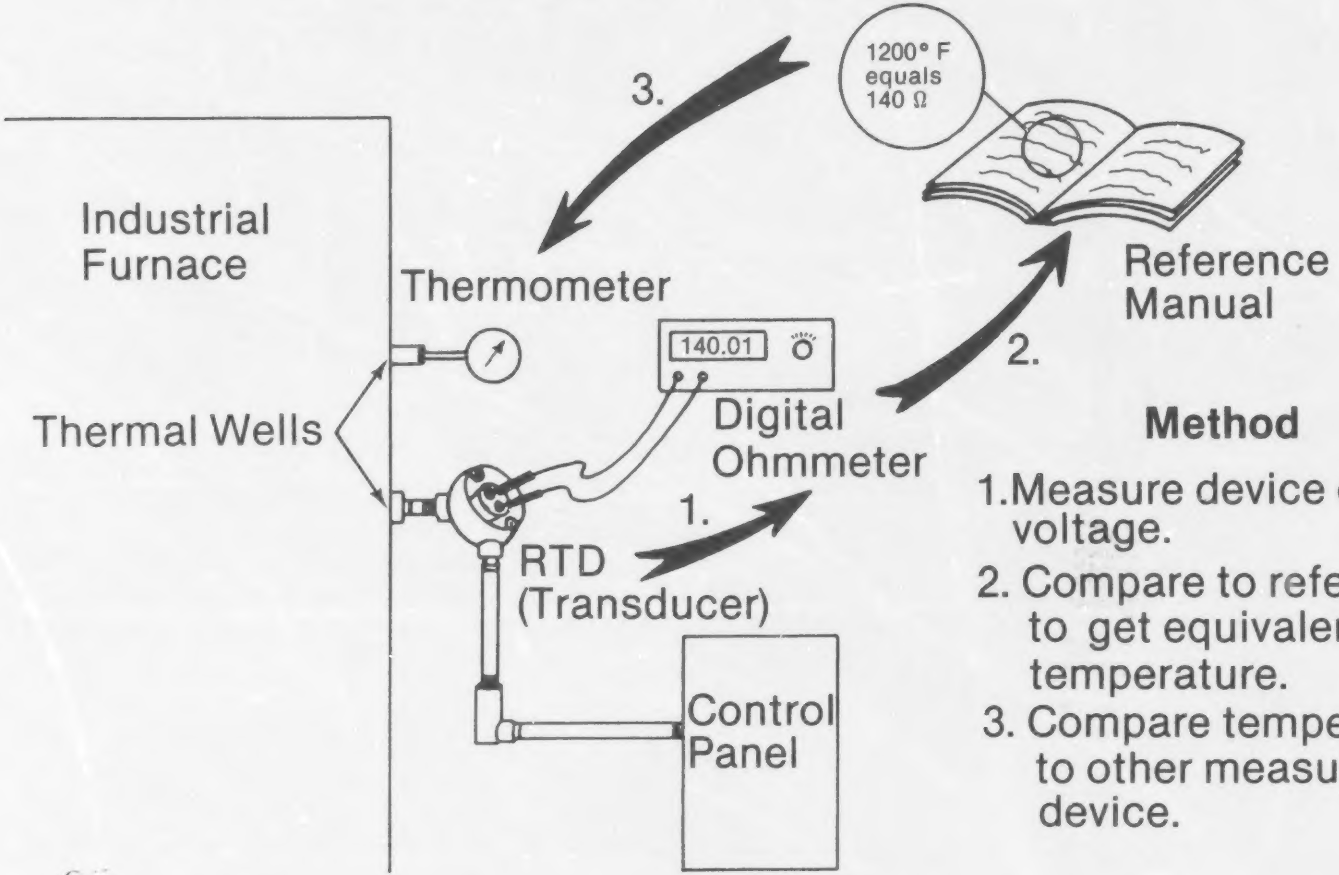
Method

1.Measure device output voltage.
2. Compare to reference to get equivalent pressure.
3.Compare pressure to other measuring device.

TM #1

AIE - 77-A

Testing or Calibrating a Temperature Transducer System



3.

1200° F
equals
140 Ω

Reference
Manual

2.

Industrial
Furnace

Thermometer

140.01

Thermal Wells

Digital
Ohmmeter

1.

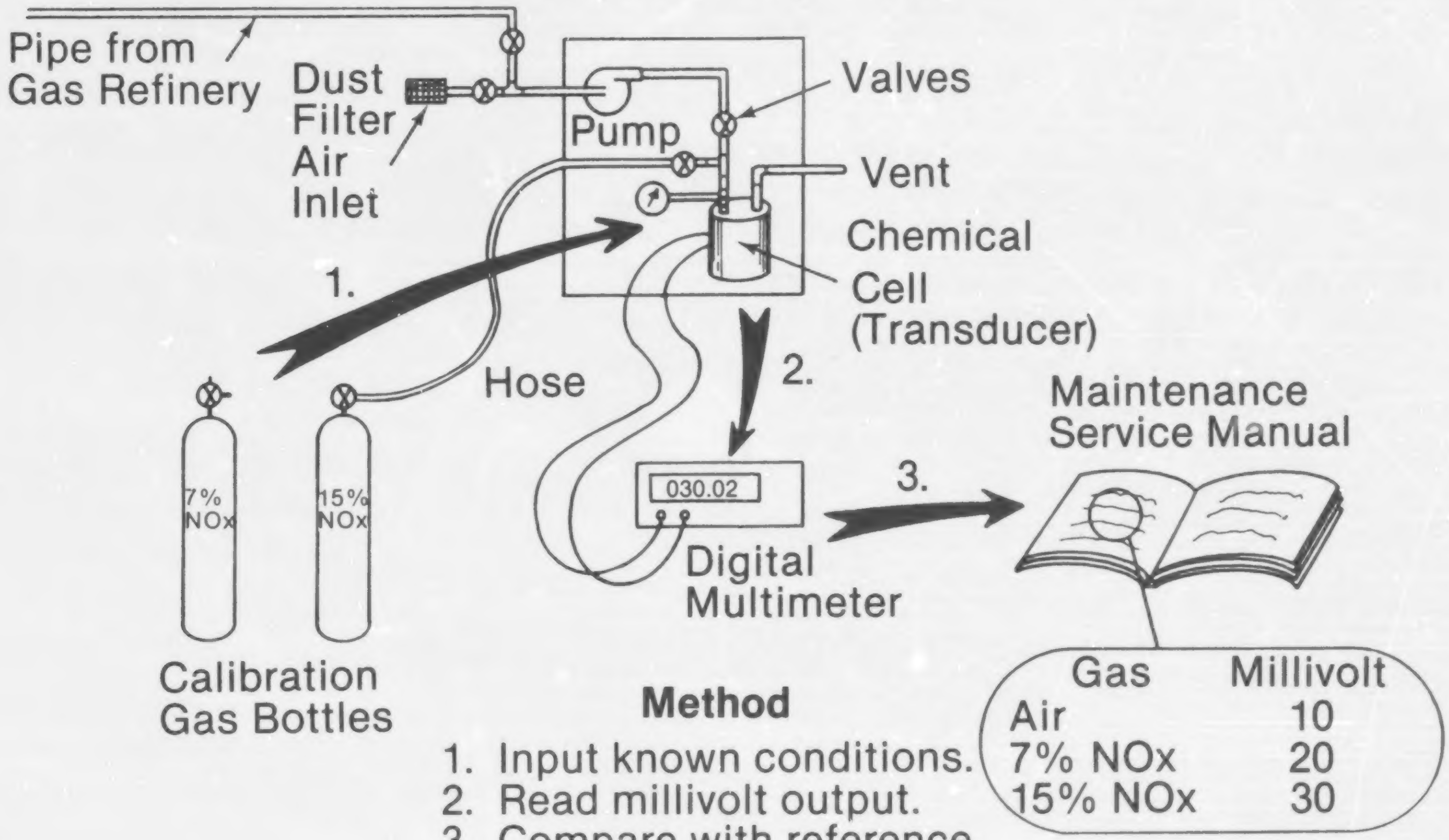
RTD
(Transducer)

Control
Panel

Method

1. Measure device output voltage.
2. Compare to reference to get equivalent temperature.
3. Compare temperature to other measuring device.

Testing or Calibrating a Chemical Detector Transducer System


Pipe from Gas Refinery
Dust Filter
Air Inlet
Pump
Valves
Vent
Chemical Cell (Transducer)
1.
Hose
2.
030.02
Digital Multimeter
3.
Maintenance Service Manual
7% NOx
15% NOx
Calibration Gas Bottles

Gas	Millivolt
Air	10
7% NOx	20
15% NOx	30

Method

1. Input known conditions.
2. Read millivolt output.
3. Compare with reference.

INDUSTRIAL USES OF TRANSDUCERS
UNIT II

ASSIGNMENT SHEET #1 — SELECT THE PROPER TRANSDUCERS FOR SPECIFIC APPLICATIONS

NAME ______________________________________ SCORE ______________

Technicians occasionally have to select a transducer to fit an industrial application. In this exercise, you will become familiar with types of transducers that you may encounter in industry.

For each statement, select the most suitable transducer to fit the application and write its number in the space. Some answers may be used more than once.

______A. Transducer used in a furnace to detect that the flame is burning; since the furnace remains hot after the flame goes out, a simple temperature detector will not work

______B. Transducer used to measure the temperature of water in a pipe

______C. Transducer used to measure the pressure of hydraulic fluid in a pipe

______D. Transducer used to detect radioactive, ionic particles

______E. Transducer used to measure the strain on a steel beam

______F. Device that varies frequency according to mechanical motion

______G. Transducer that can detect vibration in a diesel engine

______H. Device that outputs a voltage and is sensitive to changes in light intensity

1. Strain gauge
2. Thermistor
3. Resistive thermal device
4. Photoresistor
5. Potentiometer
6. Photovoltaic cell
7. Thermocouple
8. Piezoelectric crystal
9. Variable transformer
10. Chemical cell
11. Accelerometer
12. Phototube
13. Phototransistor
14. Photodiode
15. Ionic particle detector

INDUSTRIAL USES OF TRANSDUCERS
UNIT II

ASSIGNMENT SHEET #2 — SELECT THE PROPER TEST EQUIPMENT FOR VARIOUS TRANSDUCERS

NAME ____ SCORE ________________

Transducers used in industry often must be installed in distant or inaccessible places. Technicians cannot always take several test instruments to check a possibly faulty transducer; they must select the most suitable instrument.

For each transducer listed below, select the most suitable test instrument and write its number in the space. Some answers may be used more than once.

_____A. Photoresistor

_____B. Photocell

_____C. Photodiode

_____D. Chemical cell

_____E. Variable transformer

_____F. RTD (resistive thermal device)

_____G. Thermistor

_____H. Potentiometer

_____I. Thermocouple

_____J. Accelerometer

_____K. Piezoelectric crystal

1. Ohmmeter, including milliohms
2. DC voltmeter, including millivolts
3. AC voltmeter, including millivolts
4. Oscilloscope

INDUSTRIAL USES OF TRANSDUCERS
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 4, 12, 13, 14

B. 2, 3, 7

C. 8

(NOTE: With the proper mechanical linkage, this device could also be 1, 5, or 9.)

D. 15

E. 1, 8

(NOTE: With the proper mechanical linkage, this device could also be 5 or 9.)

F. 8, 11

G. 11

H. 6

Assignment Sheet #2

A. 1

B. 2

C. 1

D. 2

E. 3, 4

F. 1

G. 1

H. 1

I. 2

J. 3, 4

K. 2

INDUSTRIAL USES OF TRANSDUCERS
UNIT II

JOB SHEET #1 — ANALYZE A PHOTOTRANSISTOR LIGHT-DETECTOR CIRCUIT

I. Equipment and materials

 A. Laboratory DC variable power supply

 B. Phototransistor, type MRD-300 or equivalent

 C. Darlington amplifier, type MPS-A14 or equivalent

 D. SCR, type 276-1020, or SK 3502, or equivalent 6-ampere, 200-volt device

 E. Lamp, 15 volt

 F. Oscilloscope

 G. Breadboard

 H. Fixed resistors, 1/4 watt

  1. 3.3 kohm

  2. 200 kohm

  3. 4.7 kohm

  4. 10 kohm

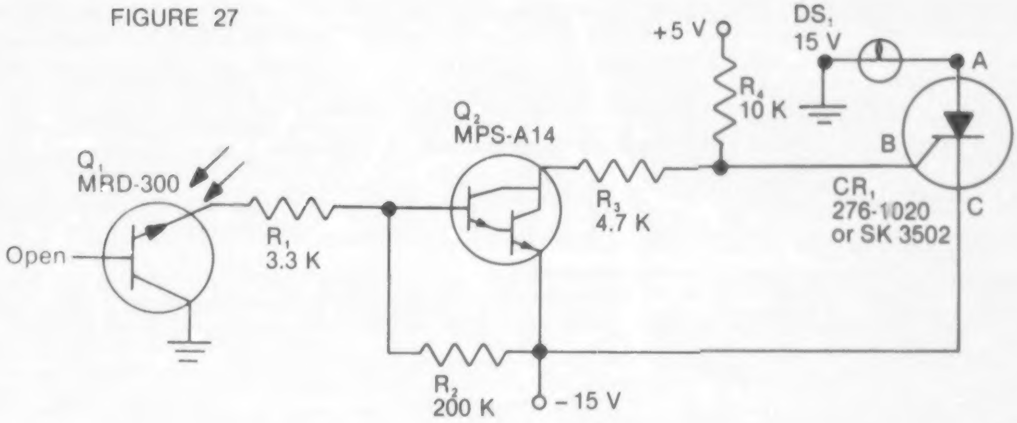
 I. Circuit wiring

JOB SHEET #1

II. Procedure

A. Construct the circuit shown in Figure 27

FIGURE 27


+5 V
DS₁
15 V
A
R₄
10 K
Q₂
MPS-A14
B
Q₁
MRD-300
R₃
4.7 K
CR₁
276-1020
or SK 3502
C
Open
R₁
3.3 K
R₂
200 K
– 15 V

(NOTE: Have the instructor check your circuit.)

B. Set power supply voltages as shown in Figure 27

(NOTE: The SCR should trigger the lamp on and off as the phototransistor is covered and uncovered. You may have to position the workbench light very near the phototransistor.)

C. View voltage level changes at emitter of Q1, collector of Q2, and gate of CR1, using the oscilloscope

D. Record voltage levels as "high" or "low" in Table 1

TABLE 1

	Phototransistor Window	
	Covered	Uncovered
Q1 emitter		
Q2 collector		
CR1 gate		
Lamp DS1 (on or off?)		

E. Would a circuit such as this control outdoor lighting according to sunlight?

____

(NOTE: Show your results to the instructor.)

F. Put away equipment and materials

INDUSTRIAL USES OF TRANSDUCERS
UNIT II

JOB SHEET #2 — ANALYZE THE OUTPUT OF A PRESSURE TRANSDUCER

I. Equipment and materials

   A. Pressure transducer having a range of 0 to 20 psi

   B. Oscilloscope

   C. Eye protection

   D. Compressed air, hose, and nozzle

   E. Small vise

II. Procedure

   A. Connect transducer terminals to oscilloscope probe and ground clip

   B. Set oscilloscope to millivolt operation and turn on power

   C. Clamp transducer in vise so that pressure-sensing end can be blasted with air nozzle

   D. Put on eye protection

   E. Blast transducer with compressed air; observe oscilloscope display

   (CAUTION: Always wear eye protection when using compressed air.)

   F. Move compressed air nozzle first closer and then farther from transducer to observe its sensitivity

      1. What was the maximum millivolt deflection observed?

      ____

      2. How far away from the transducer could the air blast still be detected?

      ____

   (NOTE: Show your results to the instructor.)

   G. Turn off power

   H. Put away equipment and materials

INDUSTRIAL USES OF TRANSDUCERS
UNIT II

JOB SHEET #3 — CONSTRUCT AND TEST A VARIABLE TRANSFORMER TRANSDUCER

I. Equipment and materials

   A. Dual-trace oscilloscope, with two probes

   B. Frequency generator (oscillator), audible frequency range

   C. Solid copper wire, approximately 6 feet, insulated, from #14 AWG to #20 AWG

   D. Wire cutters and strippers

   E. Soldering iron or gun, from 20 to 60 watts

   F. 60/40 rosin, electrical solder

   G. Smooth, soft iron or mild steel rod from 1/4-inch to 3/8-inch diameter, approximately 8 inches in length

   H. Resistor, any size or variable, between 100 ohms and 1 kohm

II. Procedure

   A. Cut the length of insulated wire in half

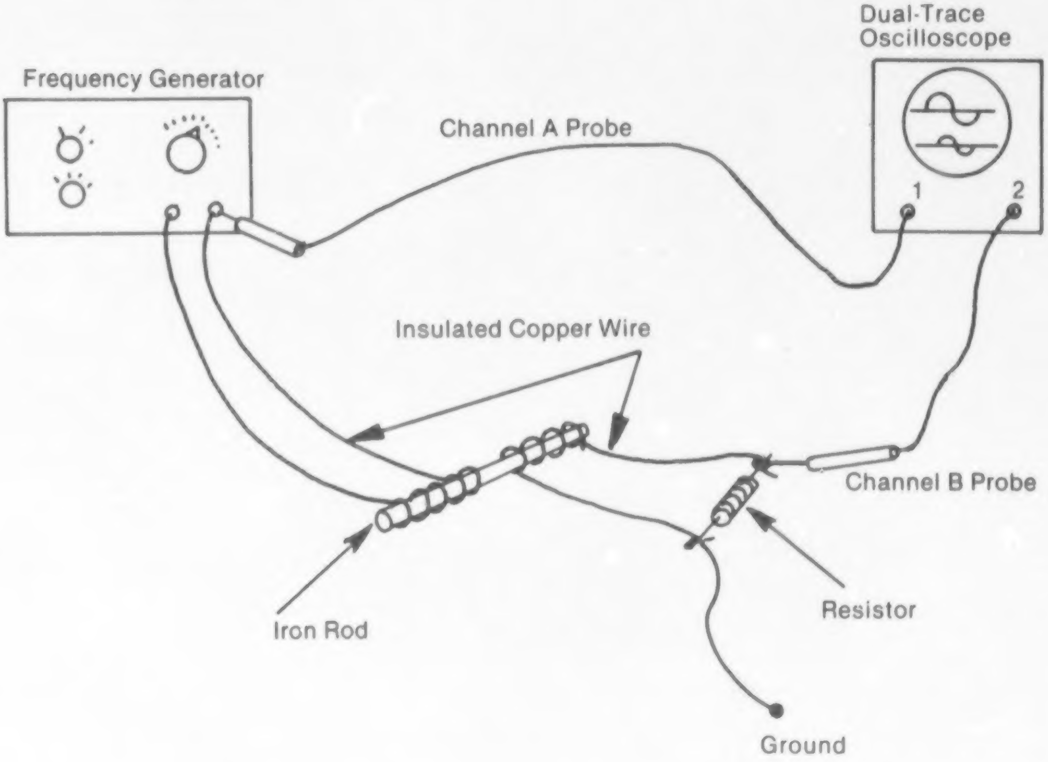
   B. Strip the insulation approximately 1 inch from each end of the two wires

JOB SHEET #3

C. Wrap each wire about five turns on opposite ends of the iron rod (Figures 28 and 29)

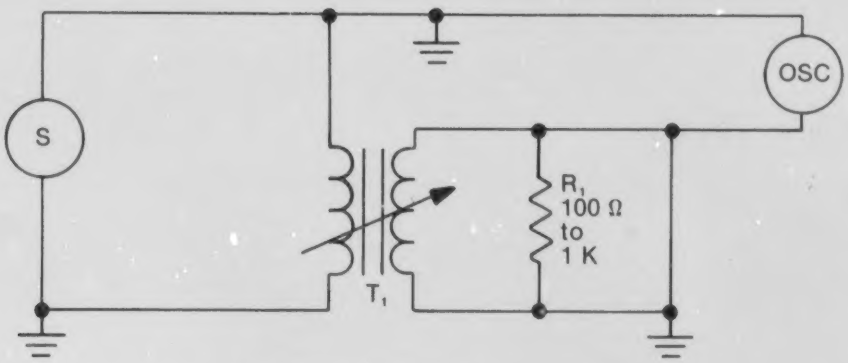
(NOTE: In this instance, the direction of the wrap is not particularly important.)

FIGURE 28


Dual-Trace Oscilloscope
Frequency Generator
Channel A Probe
1
2
Insulated Copper Wire
Channel B Probe
Resistor
Iron Rod
Ground

JOB SHEET #3

FIGURE 29



Equivalent Schematic

D. Solder resistor across one coil

E. Connect frequency generator and oscilloscope as shown in Figure 28

F. Set generator for approximately half-power output

(NOTE: Select approximately 200 hertz.)

G. Adjust oscilloscope vertical sensitivity and sweep rate for a stable, dual-trace display representing both input and output of transformer

H. Adjust generator frequency while observing transformer output on oscilloscope

(NOTE: Some frequencies will pass through the transformer with less loss than others. To indicate this, the amplitude of the transformer output waveform will peak and then diminish again as the range of the generator varies.)

I. Select a frequency that your particular transformer transmits well; record that frequency above Table 2 on next page

J. Record the input amplitude and output amplitude in Table 2 as millivolts, peak-to-peak

K. Move the two coils closer together

JOB SHEET #3

L. Record the input and output amplitudes in Table 2

M. Continue moving coils closer together, while recording your readings, until the table is completed

N. Turn off power

O. Show your table of readings to the instructor

TABLE 2

VARIABLE TRANSFORMER DATA TABLE

Frequency ____________________

Amplitudes	
Input, mV pk-pk	Output, mV pk-pk

P. Put away equipment and materials

(NOTE: This type of apparatus is used as a transducer to measure the position of a mechanical part connected to one coil of the transformer so that it moves as the part moves. The output signal is then transmitted to a remote control or monitoring station.)

INDUSTRIAL USES OF TRANSDUCERS
UNIT II

JOB SHEET #4 — CONSTRUCT AND TEST A HALL-EFFECT SENSOR CIRCUIT

I. Equipment and materials

A. DC power supply, 4.5 to 5.5 volt or 6 to 16 volt

B. Hall-effect sensor, Microswitch

C. Magnet-Microswitch

D. Resistor, 300 ohm

E. Resistor, 10 kohm

F. Triac, #2N6071 or equivalent

G. Keyless lamp socket

H. Lamp, 60 watt, 120 volt

I. Circuit wiring

J. Connection to 120-volt power supply

K. Breadboard

L. SPST switch

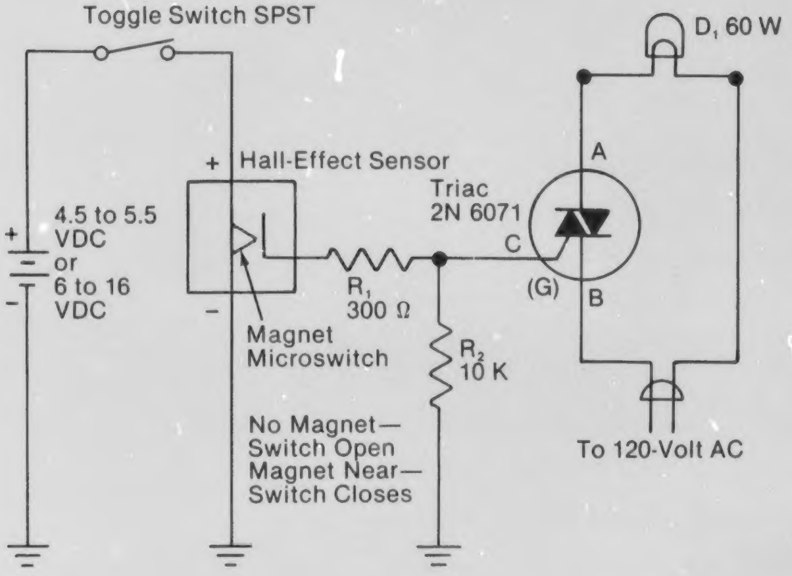
M. Bar magnet

JOB SHEET #4

II. Procedure

A. Construct circuit shown in Figure 30

FIGURE 30


Toggle Switch SPST
D_1 60 W
+
Hall-Effect Sensor
A
Triac
2N 6071
C
(G)
B
+
4.5 to 5.5
VDC
or
6 to 16
VDC
-
-
R_1
300 Ω
Magnet
Microswitch
R_2
10 K
No Magnet—
Switch Open
Magnet Near—
Switch Closes
To 120-Volt AC

B. Plug lamp into 120-volt power supply

C. Close DC switch

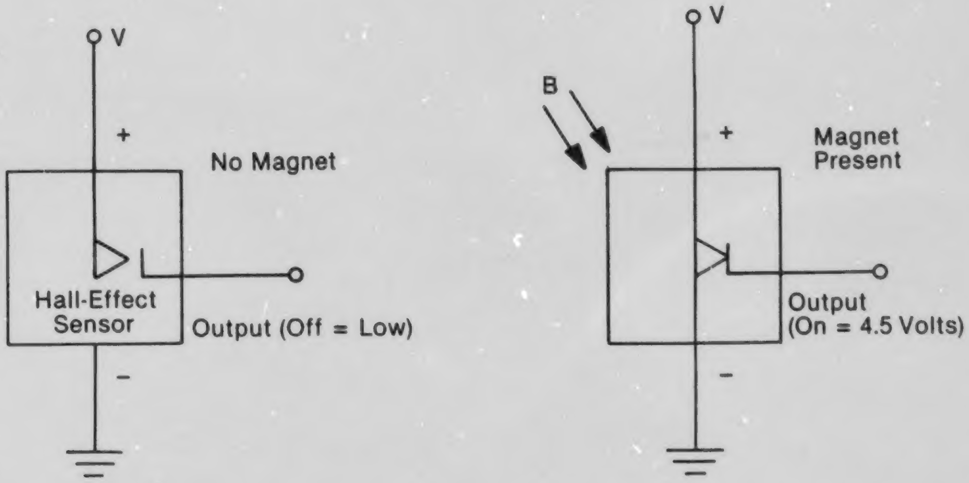
(NOTE: No action will be visible.)

JOB SHEET #4

D. Bring bar magnet near enough to Hall-effect sensor to cause triggering of Triac (Figure 31)

(NOTE: The light will come on. The Hall voltage is dependent on the presence of the magnetic field and on the current flowing in the element. If either the current or the magnetic field is removed, the output of the Hall generator is zero.)

FIGURE 31


V
+
No Magnet
Hall-Effect Sensor
Output (Off = Low)
–
V
B
+
Magnet Present
Output (On = 4.5 Volts)
–

Used with permission of MICRO SWITCH, a division of Honeywell.

E. Turn off power

F. Put away equipment and materials

INDUSTRIAL USES OF TRANSDUCERS
UNIT II

TEST

NAME ______________________________________ SCORE ______________

1. Match terms associated with transducers to their correct definitions. Write the correct numbers in the blanks. Terms and definitions are continued on the next page.

______a. Device used to measure amount of impurities in a liquid by passing a light beam through the liquid

______b. Device that measures fluid flow in a pipe by detecting the disruption of magnetic forces passing across the flow path

______c. Junction of two dissimilar metals that produces a small voltage when heated; voltage varies according to temperature

______d. Device that can be attached to mechanical parts to measure slight bending, crushing, or stretching

______e. Transducer whose voltage output varies in reaction to a particular chemical

______f. Device made from permanent magnet, strain gauge, or crystal; used to measure the acceleration and amplitude of vibration

______g. Any of the physical properties that constitute the environment

______h. Device used to measure the density of gases, particularly smokestack gases, by passing a light beam through the gases

______i. Device for measuring flow by measuring the rotation of a fan or turbine as the flow rotates it

______j. Strip formed of two dissimilar metals with different heat expansion properties that cause bending to occur when heat varies

______k. Device that converts energy from one form to another at a known rate; may be used as a sensor

1. Transducer
2. Parameters
3. Turbidity meter
4. Bimetal strip
5. Thermocouple
6. Opacity meter
7. Strain gauge
8. Turbine meter
9. Accelerometer
10. Electromagnetic fluid-flow detector
11. Chemical cell

TEST

_____l. Device that measures flow by the rate and number of piston movements necessary to pump the fluid

_____m. Conducting electricity at various levels depending upon amount of light exposure; similar to photoresistive

_____n. Generating voltage output as a result of light exposure

_____o. Changing resistance as a result of light exposure

_____p. Releasing electrons as a result of light exposure

12. Positive displacement meter
13. Photovoltaic
14. Photoconductive
15. Photoresistive
16. Photoemissive

2. Match abbreviations and symbols associated with transducers to their correct interpretations. Write the correct numbers in the blanks. Abbreviations and symbols are continued on the next page.

_____a. Change in

_____b. Pounds per square inch

_____c. Pounds per square inch, gauge

_____d. Pressure transmitter

_____e. Microphone

_____f. Ultraviolet

_____g. Transformer

_____h. Transmitter

_____i. Light

_____j. Thermocouple

_____k. Flow transmitter

_____l. Resistive thermal device

_____m. Pounds per square inch, absolute

_____n. Transducer

1. XMTR
2. XDCR
3. λ
4. UV
5. psig
6. Δ
7. Mic
8. XFMR
9. psia
10. psi
11. PT
12. FT
13. RTD
14. TC

TEST

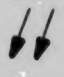
______o. Parts of hydrogen (acidity measured as positive ions)

______p. Temperature effect

______q. Crystal

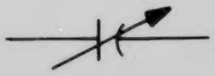
______r. Light rays or other electromagnetic radiation

______s. Infrared

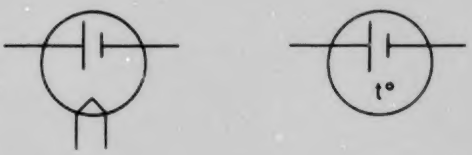
15. t°
16. 
17. IR
18. XTL
19. pH

3. Identify circuit and diagram symbols associated with transducers. Write the name of the symbol in the blank below each picture.

Potentiometer
Photoresistor (photoconductive cell)
Thermocouple
Temperature switches
Thermistor
Flow switches
Grounded, shielded wire
Variable resistor
RTD with independent integral heater
Crystal
Photocell) (photovoltaic cell)
Variable inductor
Variable transformer
Phototube (photoemissive cell)
Pressure switches
Liquid-level switches
Variable capacitor

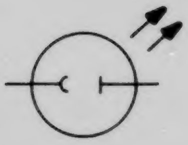


a. ________________________________

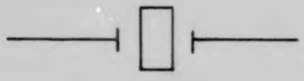


b. ________________________________

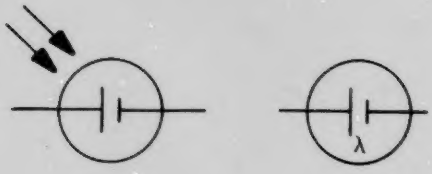
TEST



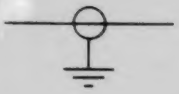
c. ______________________________



d. ______________________________

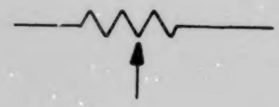


e. ______________________________

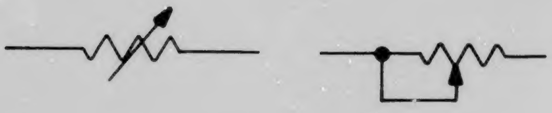


f. ______________________________

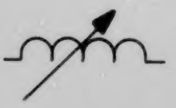
TEST



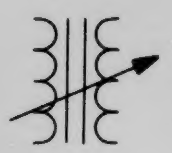
g. ______________________________



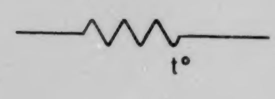
h. ______________________________



i. ______________________________

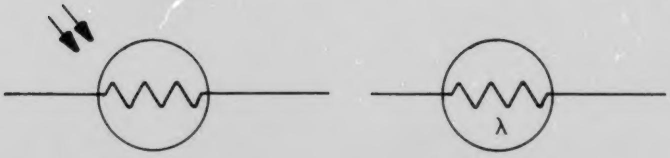


j. ______________________________

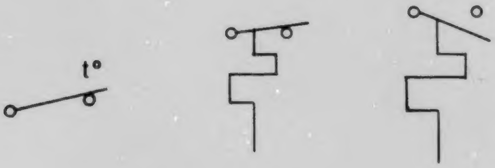


k. ______________________________

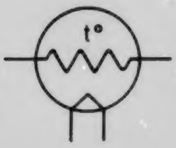
TEST



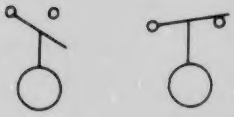
l. ______________________________



m. ______________________________

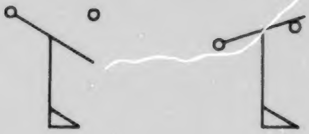


n. ______________________________

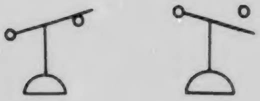


o. ______________________________

TEST



p. ______________________________



q. ______________________________

4. Classify transducers according to their outputs. Write the correct numbers in the blanks. Blanks may contain more than one answer.

_____a. Thermistor

_____b. Strain gauge

_____c. Accelerometer

_____d. Ionic particle detector

_____e. Phototube

_____f. Piezoelectric crystal

_____g. Potentiometer

_____h. Photodiode

_____i. Resistive thermal device

_____j. Photovoltaic cell

_____k. Thermocouple

_____l. Phototransistor

1. Variable resistance
2. Variable voltage output
3. Variable frequency
4. Variable emission

TEST

_____m. Photoresistor

_____n. Variable transformer

_____o. Chemical cell

5. State general methods for testing or calibrating a transducer.

a. ______________________________

b. ______________________________

6. List ten parameters monitored by transducers in industrial use.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

i. ______________________________

j. ______________________________

7. List industrial applications of transducers used as detectors.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

TEST

8. Match to their correct functions agencies concerned with industrial detection systems. Write the correct numbers in the blanks.

______a. Canadian equivalent of the NBS

______b. Prescribes and regulates protection, and monitors conditions that may affect workers' health and safety

______c. Tests and approves electrical equipment for safety and effectiveness

______d. Sets standards for testing and measurement in the United States

______e. Prescribes codes for pressure vessels, testing procedures, and so forth

______f. Regulates radioactive materials, devices, and industries

______g. Regulates the control and disposal of hazardous industrial products and waste materials

______h. Regulates communications equipment and radio-frequency transmitting equipment

______i. Specifies standards for electrical and electronic equipment

______j. Prescribes codes for electrical equipment and wiring, including fire protection and detection systems; publishes the *National Electrical Code* (*NEC*)

1. Occupational Safety and Health Act (OSHA)
2. National Bureau of Standards (NBS)
3. Canadian Standards Association (CSA)
4. Underwriters' Laboratory (UL)
5. American Society of Mechanical Engineers (ASME)
6. Institute of Electrical and Electronics Engineers (IEEE)
7. Nuclear Regulatory Commission (NRC)
8. Federal Communications Commission (FCC)
9. Environmental Protection Agency (EPA)
10. National Fire Protection Association (NFPA)

(NOTE: Test questions 9-11 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

9. Select the proper transducers for specific applications.

10. Select the proper test equipment for various transducers.

TEST

11. Demonstrate the ability to

    a. Analyze a phototransistor light-detector circuit.

    b. Analyze the output of a pressure transducer.

    c. Construct and test a variable-transformer transducer.

    d. Construct and test a Hall-effect sensor circuit.

INDUSTRIAL USES OF TRANSDUCERS
UNIT II

ANSWERS TO TEST

1.

a.	3	g.	2	m.	14
b.	10	h.	6	n.	13
c.	5	i.	8	o.	15
d.	7	j.	4	p.	16
e.	11	k.	1		
f.	9	l.	12		

2.

a.	6	f.	4	k.	12	p.	15
b.	10	g.	8	l.	13	q.	18
c.	5	h.	1	m.	9	r.	16
d.	11	i.	3	n.	2	s.	17

3. a. Variable capacitor
   b. Thermocouple
   c. Phototube (photoemissive cell)
   d. Crystal
   e. Photocell (photovoltaic cell)
   f. Grounded, shielded wire
   g. Potentiometer
   h. Variable resistor
   i. Variable inductor
   j. Variable transformer
   k. Thermistor
   l. Photoresistor (photoconductive cell)
   m. Temperature switches
   n. RTD with independent integral heater
   o. Liquid-level switches
   p. Flow switches
   q. Pressure switches

ANSWERS TO TEST

4.	a.	1	e.	4	i.	1	m.	1
	b.	2	f.	2, 3	j.	2	n.	2
	c.	3	g.	1	k.	2	o.	2
	d.	4	h.	4	l.	4		

5. a. Compare operation to a second measuring device
   b. Compare operation with known conditions

6. Answer should include any ten of the following
   a. Chemicals
   b. Temperature
   c. Radioactivity
   d. Humidity
   e. Vibration
   f. Visible light
   g. Infrared light
   h. Ultraviolet light
   i. Audible sound
   j. Ultrasonics
   k. Fluid or gas flow
   l. Pressure
   m. Liquid level

7. a. Fire protection
   b. Security
   c. Traffic control

ANSWERS TO TEST

d. Pollution detection and control

e. Personnel protection

f. Process control

g. Nondestructive testing (NDT)

8.	a.	3	e.	5	i.	6
	b.	1	f.	7	j.	10
	c.	4	g.	9		
	d.	2	h.	8		

9. Evaluated to the satisfaction of the instructor

10. Evaluated to the satisfaction of the instructor

11. Performance skills evaluated to the satisfaction of the instructor

BINARY
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to make various binary calculations and conversions. The student will show this knowledge by completing assignment sheet and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with the binary numbering system to their correct definitions.
2. Match abbreviations associated with the binary numbering system to their correct terms.
3. Distinguish between decimal and binary numbering system characteristics.
4. Convert decimal numbers to binary numbers.
5. Convert binary numbers to decimal numbers.
6. Add binary numbers.
7. Subtract binary numbers.
8. Subtract binary numbers by adding complements.

BINARY
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Make transparencies.

  B. Provide students with objective sheet.

  C. Discuss unit and specific objectives.

  D. Provide students with information and assignment sheets.

  E. Discuss information and assignment sheets.

  F. Give test.

II. Instructional materials

  A. Objective sheet

  B. Suggested activities

  C. Information sheet

  D. Transparency master: TM #1 — Decimal to Binary (Division Method)

  E. Assignment Sheet #1 — Complete Mathematical Equations Using Binary Numbers

  F. Answers to assignment sheet

  G. Test

  H. Answers to test

III. Unit references

  A. Malvino, Albert P. *Digital Computer Electronics.* New York: McGraw-Hill, 1977.

  B. Tokheim, Roger L. *Digital Electronics.* New York: McGraw-Hill, 1979.

BINARY
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Decimal number system — Numbering system that uses the numerals 0 through 9, thus having a base or radix of 10

B. Binary number system — Numbering system that uses only the numerals 0 and 1, thus having a base or radix of 2

C. Least significant digit — Rightmost digit of a number; has the lowest value

D. Most significant digit — Leftmost digit of a number; has the highest value

E. Complement — Binary opposite of a number

EXAMPLES: The complement of binary 1 is 0; the complement of binary 0 is 1.

F. Binary 0 — Binary number having a zero value

G. Binary 1 — Binary number having a value greater than zero

H. Radix — Number of digits used in a system

EXAMPLES: The binary system has a radix of 2 because it uses only two numerals, 0 and 1. The decimal system has a radix of 10 because it uses ten numerals, 0 through 9.

I. Exponent — Numerical symbol written to the right of a number and raised; indicates that the number is to be raised to that power

EXAMPLES: In the numbers 7^2, 4^8, the raised 2 and 8 are exponents.

J. Weighted number — Radix and the exponent assigned to each binary digit, beginning with the exponent 0 for the least significant digit; used to convert a binary number to a decimal number

EXAMPLES: 2^2, 2^0

K. Place value — Worth of each numeral according to its position in the number

EXAMPLES: In the decimal number 333, the 3 on the left is worth 300, the middle 3 is worth 30, and the 3 on the right is worth 3.

In the binary number 111, the 1 on the left is worth 4, the middle 1 is worth 2, and the 1 on the right is worth 1.

INFORMATION SHEET

II. Abbreviations associated with binary numbering system

  A. LSD — Least significant digit

  B. MSD — Most significant digit

  C. 1 — Binary one

  D. 0 — Binary zero

III. Characteristics of decimal and binary numbering systems

  A. Decimal numbering system

    1. Requires the use of digits 0 through 9

    2. Is called base 10 numbering system

    3. Increases place value of numbers in multiples of ten

EXAMPLE: In the decimal number 452 (four hundred fifty-two), the least significant digit (2) represents units, the second number (5) represents tens, and the third number (4) represents hundreds.

		Hundreds		Tens		Units
452	=	400	+	50	+	2

  B. Binary numbering system

    1. Requires the use of digits 0 and 1 only

    2. Is called a base 2 numbering system

    3. Increases place value of numbers in multiples of two

EXAMPLE: In the binary number 1010, (stated one, zero, one, zero), the zero on the far right is the least significant digit, which represents the 1's count. The next number represents the 2's count, and the next number represents the 4's count. Each number is double the value of the previous number or count.

etc.	512	256	128	64	32	16	8	4	2	1

INFORMATION SHEET

IV. Converting a decimal number to a binary number (Assignment Sheet #1)

(NOTE: Either the comparison method or the division method may be used to convert decimal numbers to binary numbers.)

A. Comparison method

1. Using a binary conversion table, put a 1 in the column having the place value that is the same or the largest of all those that are less than the decimal number

EXAMPLE: Convert the decimal number 54 to a binary number.

	512	256	128	64	32	16	8	4	2	1	Conversion table
54 =					1						Binary number

2. Subtract that place value from the decimal number

EXAMPLE: 54 − 32 = 22

3. Put a 1 in the column having the place value that is the same or the largest of all those that are less than the remainder in the previous step

EXAMPLE:	512	256	128	64	32	16	8	4	2	1	Conversion table
54 =					1	1					Binary number

4. Subtract the place value from the remainder

EXAMPLE: 22 − 16 = 6

5. Repeat steps 3 and 4 until the remainder is 0

EXAMPLE:	512	256	128	64	32	16	8	4	2	1	Conversion table
54 =					1	1		1			Binary number
6 − 4 = 2					1	1		1	1		
2 − 2 = 0											

6. Place a 0 in each column that does not have a 1

54 = 110110

INFORMATION SHEET

B. Division method (Transparency #1)

1. Divide the original decimal number by the radix (two); the remainder will become the LSD, either a one or a zero

   EXAMPLE: Convert the decimal number 54 to a binary number.

$$\begin{array}{rl} 27 & \\ 2\overline{)54} & \\ \underline{4} & \\ 14 & \\ \underline{14} & \\ 0 & \text{Remainder} \end{array}$$

2. Divide the new quotient by two, noting the remainder as the next binary number

   EXAMPLE:

$$\begin{array}{rrl} 13 & 27 & \\ 2\overline{)27} & 2\overline{)54} & \\ \underline{2} & \underline{4} & \\ 7 & 14 & \\ \underline{6} & \underline{14} & \\ 1 & 0 & \text{Remainders} \end{array}$$

3. Repeat step 2 until the quotient is zero and the remainder is 1, which becomes the MSD

   EXAMPLE:

$$\begin{array}{rrrrrr} 0 & 1 & 3 & 6 & 13 & 27 \\ 2\overline{)1} & 2\overline{)3} & 2\overline{)6} & 2\overline{)13} & 2\overline{)27} & 2\overline{)54} \\ \underline{0} & \underline{2} & \underline{6} & \underline{12} & \underline{26} & \underline{54} \\ 1 & 1 & 0 & 1 & 1 & 0 \end{array}$$

The binary number is 110110.

INFORMATION SHEET

V. Converting binary numbers to decimal numbers (Assignment Sheet #1)

(NOTE: Either the comparison method or the weighted method may be used to convert binary numbers to decimal numbers.)

A. Comparison method

1. Using a binary conversion table and beginning with the LSD, note the place value of each binary 1

EXAMPLE: Convert the binary number 110110 to a decimal number.

512	256	128	64	32	16	8	4	2	1	Conversion table
				1	1	0	1	1	0	Binary number

2. Add the place values of each binary 1 to determine the decimal number equivalent

EXAMPLE:

512	256	128	64	32	16	8	4	2	1	Conversion table
				1	1	0	1	1	0	Binary number
				32+	16+	0+	4+	2+	0	Place values
									54	Decimal equivalent

B. Weighted method

1. Designate each binary digit with a weighted number, beginning with the exponent 0 for the LSD and working from right to left

EXAMPLE:

1	1	0	1	1	0	Binary number
2^5	2^4	2^3	2^2	2^1	2^0	Weighted numbers

2. Convert the weighted number for each binary 1 to its decimal equivalent

(NOTE: Each binary 0 remains 0.)

EXAMPLE:

1	1	0	1	1	0	Binary number
2^5	2^4	2^3	2^2	2^1	2^0	Weighted numbers
32	16	0	4	2	0	Weighted conversions

3. Total the weighted conversions to determine the decimal number

EXAMPLE: $32 + 16 + 0 + 4 + 2 + 0 = 54$

INFORMATION SHEET

VI. Adding binary numbers (Assignment Sheet #1)

A. Place the binary numbers to be added in a column, with the LSDs directly below each other

B. Add the columns, beginning with the LSDs and following basic binary addition:

0 + 0 = 0
0 + 1 = 1
1 + 1 = 0, with a 1 carry

EXAMPLES:

$$\begin{array}{cccc} & 1 & & \\ & & 1 & 0 \\ + & & 1 & 1 \\ \hline & 1 & 0 & 1 \end{array} \qquad \begin{array}{cccccc} & 1 & 1 & & & \\ & & 1 & 1 & 1 & 0 \\ + & & 1 & 1 & 0 & 0 \\ \hline & 1 & 1 & 0 & 1 & 0 \end{array} \qquad \begin{array}{l} \text{Carried numbers} \\ \\ \\ \\ \end{array}$$

(NOTE: The results may be checked by converting the binary numbers to decimal numbers and adding.)

VII. Subtracting binary numbers (Assignment Sheet #1)

(NOTE: The results may be checked by changing the binary numbers into decimal numbers and subtracting.)

A. Place the binary numbers to be calculated in a column, with the LSDs directly beneath each other

EXAMPLES: Subtract 101 from 111.

$$\begin{array}{rl} 111 & \text{Minuend} \\ \underline{-\ 101} & \text{Subtrahend} \end{array}$$

B. Subtract the columns, beginning with the LSD and following basic binary subtraction:

0 − 0 = 0
1 − 0 = 1
1 − 1 = 0
0 − 1 = 1, with 1 borrowed from left column

(NOTE: In the case of 0 − 1, there may not be a one in the adjacent left column. The first column to the left that does contain a one gives it to the 0 − 1 column. The donor column digit becomes a zero, and each zero in the minuend between donor and recipient becomes a one.)

EXAMPLES:

$$\begin{array}{cccc} & 0 & 1 & 10 \\ & \cancel{1} & \cancel{0} & \cancel{0} \\ - & & & 1 \\ \hline & & 1 & 1 \end{array} \qquad \begin{array}{ccccccc} & 0 & 1 & 1 & 10 & 0 & 10 \\ & \cancel{1} & \cancel{0} & \cancel{0} & \cancel{0} & \cancel{1} & \cancel{0} \\ - & & & & 1 & 0 & 1 \\ \hline & & 1 & 1 & 1 & 0 & 1 \end{array}$$

INFORMATION SHEET

VIII. Subtracting binary numbers by adding complements (Assignment Sheet #1)

(NOTE: In digital circuitry a subtrahend may be used as an addend by complementing the binary. The results may be checked by changing the binary numbers to decimal numbers and subtracting.)

A. Place the subtrahend under the minuend, with LSDs in same column

B. Change the subtrahend to its complement by changing each zero to a one and each one to a zero

EXAMPLE: $\begin{array}{r} 101 \\ \underline{-011} \end{array}$ becomes $\begin{array}{r} 101 \\ \underline{100} \end{array}$

C. Add the minuend to the complement

EXAMPLE:

$$\begin{array}{r} {}^{1} \\ 101 \\ \underline{+100} \\ 1001 \end{array}$$

(NOTE: The answer now contains an extra digit, which is moved from the MSD position to the LSD position.)

D. Remove the left-most digit and add it to the LSD

EXAMPLE:

$$\begin{array}{rl} {}^{1} & \\ 101 & \text{Minuend} \\ \underline{+100} & \text{Complement of subtrahend} \\ \enclose{circle}{1}001 & \text{Subtotal} \\ \underline{+\rightarrow 1} & \text{End-around carry} \\ 010 & \text{Sum} \end{array}$$

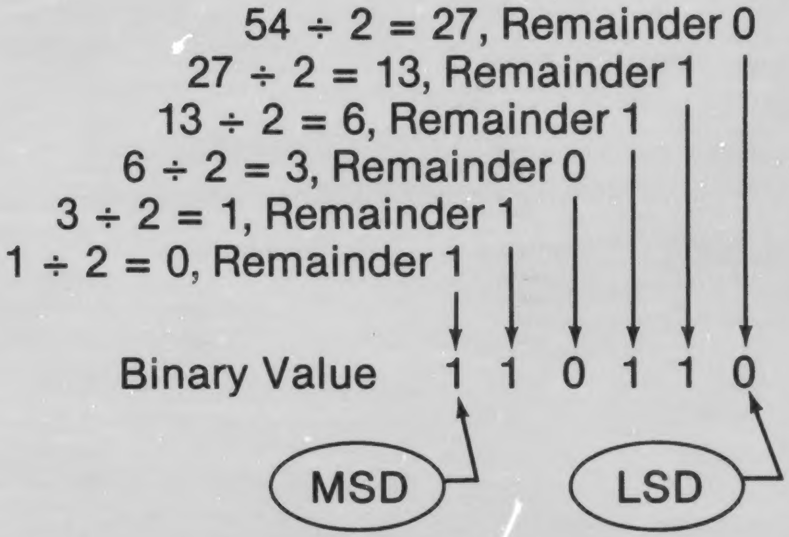
✓

(NOTE: The sum is the difference between the original minuend and the subtrahend.)

Decimal to Binary

(Division Method)

54 — Original Decimal Number



54 ÷ 2 = 27, Remainder 0
27 ÷ 2 = 13, Remainder 1
13 ÷ 2 = 6, Remainder 1
6 ÷ 2 = 3, Remainder 0
3 ÷ 2 = 1, Remainder 1
1 ÷ 2 = 0, Remainder 1

Binary Value 1 1 0 1 1 0

MSD

LSD

BINARY
UNIT I

ASSIGNMENT SHEET #1 — COMPLETE MATHEMATICAL EQUATIONS USING BINARY NUMBERS

NAME ______________________________ SCORE ______________

While working with digital electronics, computer-controlled circuitry, and other computer-asociated equipment, you will have occasions when numeric conversions and calculations will be necessary.

Complete the following computations in the spaces provided. The problems may be checked by using the equivalent decimal numbers.

A. Convert each of the following decimal numbers to a binary number.

1. 3= ______________
2. 8= ______________
3. 10= ______________
4. 43= ______________
5. 82= ______________
6. 97= ______________
7. 127= ______________
8. 144= ______________
9. 341= ______________

B. Express each of the following binary numbers as a decimal number.

1. 101= ______
2. 1001= ______
3. 10111= ______
4. 100111= ______
5. 111100= ______
6. 1100100= ______
7. 11010010= ______
8. 111000010= ______
9. 1101100000= ______

C. Add the following binary numbers.

1. $\begin{array}{r} 100 \\ +\ 11 \\ \hline \end{array}$

2. $\begin{array}{r} 11 \\ +\ 1 \\ \hline \end{array}$

3. $\begin{array}{r} 111 \\ +\ 100 \\ \hline \end{array}$

4. $\begin{array}{r} 10 \\ +\ 11 \\ \hline \end{array}$

5. $\begin{array}{r} 1010 \\ +\ 111 \\ \hline \end{array}$

6. $\begin{array}{r} 10011 \\ +\ 111 \\ \hline \end{array}$

ASSIGNMENT SHEET #1

7. 1110 + 101	8. 1111 + 1001	9. 1010 + 100

D. Subtract each of the following numbers.

1. 1010 – 101	2. 1111 – 111	3. 100 – 10
4. 10010 – 11	5. 1000 – 01	6. 111 – 100
7. 1001 – 110	8. 11 – 10	9. 1111 – 100

E. Subtract each of the following by adding complements.

1. 1000 – 0111	2. 101 – 011	3. 1101 – 0010
4. 1001 – 0111	5. 1010 – 0011	6. 1111 – 1101
7. 1011 – 0110	8. 1100 – 0110	11000 – 1000

BINARY
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A.
1. 11
2. 1000
3. 1010
4. 101011
5. 1010010
6. 1100001
7. 1111111
8. 10010000
9. 101010101

B.
1. 5
2. 9
3. 23
4. 39
5. 60
6. 100
7. 210
8. 450
9. 864

C.
1. 0111
2. 100
3. 1011
4. 101
5. 10001
6. 11010
7. 10011
8. 11000
9. 1110

D.
1. 0101
2. 1000
3. 0010
4. 1111
5. 0111
6. 0011
7. 0011
8. 0001
9. 1011

E.
1. 0001
2. 0010
3. 1011
4. 0010
5. 0111
6. 0010
7. 0101
8. 0110
9. 10000

BINARY
UNIT I

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with the binary numbering system to their definitions. Write the correct numbers in the blanks.

_____a. Leftmost digit of a number; has the highest value

_____b. Numbering system that uses the numerals 0 through 9, thus having a base or radix of 10

_____c. Number of digits used in a system

_____d. Numbering system that uses only the numerals 0 and 1, thus having a base or radix of 2

_____e. Radix and the exponent assigned to each binary digit, beginning with the exponent 0 for the least significant digit; used to convert a binary number to a decimal number

_____f. Binary number having a zero value

_____g. Binary opposite of a number

_____h. Numerical symbol written to the right of a number and raised; indicates that the number is to be raised to that power

_____i. Worth of each numeral according to its position in the number

_____j. Binary number having a value greater than zero

_____k. Rightmost digit of a number; has the lowest value

1. Decimal number system
2. Binary number system
3. Least significant digit
4. Most significant digit
5. Complement
6. Binary 0
7. Binary 1
8. Weighted number
9. Radix
10. Exponent
11. Place value

TEST

2. Match abbreviations associated with the binary numbering system to their correct terms. Write the correct numbers in the blanks.

______a.	Binary one	1. LSD
______b.	Least significant digit	2. MSD
______c.	Binary zero	3. 1
______d.	Most significant digit	4. 0

3. Distinguish between decimal and binary numbering system characteristics. Write a "D" in the blanks before decimal, and a "B" in the blanks before binary characteristics.

______a. Increases place value of numbers in multiples of ten

______b. Requires the use of digits 0 and 1 only

______c. Is called base 10 numbering system

______d. Increases place value of numbers in multiples of two

______e. Is called a base 2 numbering system

______f. Requires the use of digits 0 through 9

4. Convert the following decimal numbers to binary numbers.

a. 20 = __________ b. 56 = __________ c. 163 = __________

5. Convert the following binary numbers to decimal numbers.

a. 100 = __________ b. 10001 = __________ c. 11001100 = __________

TEST

6. Add the following binary numbers.

a. $\begin{array}{r} 1010 \\ +\ 10 \\ \hline \end{array}$ b. $\begin{array}{r} 1100 \\ +\ 1101 \\ \hline \end{array}$ c. $\begin{array}{r} 1011011 \\ +\ 111011 \\ \hline \end{array}$

7. Subtract the following binary numbers.

a. $\begin{array}{r} 111 \\ -\ 101 \\ \hline \end{array}$ b. $\begin{array}{r} 1101 \\ -\ 111 \\ \hline \end{array}$ c. $\begin{array}{r} 110101 \\ -\ 11000 \\ \hline \end{array}$

8. Subtract the following binary numbers by adding complements.

a. $\begin{array}{r} 0101 \\ -\ 0010 \\ \hline \end{array}$ b. $\begin{array}{r} 1101 \\ -\ 101 \\ \hline \end{array}$ c. $\begin{array}{r} 1100110 \\ -\ 111001 \\ \hline \end{array}$

BINARY
UNIT I

ANSWERS TO TEST

1.	a.	4	e.	8	i.	11
	b.	1	f.	6	j.	7
	c.	9	g.	5	k.	3
	d.	2	h.	10		

2.	a.	3	c.	4
	b.	1	d.	2

3.	a.	D	d.	B
	b.	B	e.	B
	c.	D	f.	D

4.	a.	10100
	b.	111000
	c.	10100011

5.	a.	4
	b.	17
	c.	204

6.	a.	1100
	b.	11001
	c.	10010110

ANSWERS TO TEST

7. a. 010
   b. 0110
   c. 011101

8. a. 0011
   b. 1000
   c. 0101101

BINARY LOGIC
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to discuss binary logic and the operation of various logic gates. The student will show this knowledge by completing assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with binary logic to their correct definitions.
2. Match abbreviations and symbols associated with binary logic to their correct definitions.
3. Distinguish among representations of logic gates.
4. Identify equivalent gates for various inverted gates.
5. Construct logic circuit diagrams from Boolean expressions.
6. Identify equivalent NAND gate circuits for various logic gates.
7. Identify integrated circuit pin configurations.
8. Demonstrate the ability to
    a. Observe the operation of AND gates.
    b. Observe the operation of OR gates.
    c. Observe the operation of NOT gates.
    d. Observe the operation of exclusive OR gates.
    e. Observe the operation of NAND gates in various configurations.

BINARY LOGIC
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

- A. Make transparencies.
- B. Provide students with objective sheet.
- C. Discuss unit and specific objectives.
- D. Provide students with information, assignment, and job sheets.
- E. Discuss information and assignment sheets.
- F. Demonstrate and discuss procedures outlined in job sheets.
- G. Demonstrate logic gates by using switches in place of gates.
- H. Give test.

II. Instructional materials

- A. Objective sheet
- B. Suggested activities
- C. Information sheet
- D. Transparency masters
    1. TM #1 — Basic Logic Gates
    2. TM #2 — Negated Circuit Outputs
    3. TM #3 — Negating Inputs
    4. TM #4 — Negating Inputs and Outputs
    5. TM #5 — Logic Circuit Construction
- E. Assignment sheets
    1. Assignment Sheet #1 — Identify Integrated Circuit Pin Configurations
    2. Assignment Sheet #2 — Construct Logic Circuit Diagrams from Boolean Equations

SUGGESTED ACTIVITIES

F. Answers to assignment sheets

G. Job sheets

  1. Job Sheet #1 — Observe the Operation of AND Gates

  2. Job Sheet #2 — Observe the Operation of OR Gates

  3. Job Sheet #3 — Observe the Operation of NOT Gates

  4. Job Sheet #4 — Observe the Operation of Exclusive OR Gates

  5. Job Sheet #5 — Observe the Operation of NAND Gates in Various Configurations

H. Test

I. Answers to test

III. Unit references

A. Malvino, Albert P. *Digital Computer Electronics.* New York: McGraw-Hill, 1977.

B. Pasahow, Edward. *Integrated Circuits for Electronics Technicians.* New York: McGraw-Hill, 1979.

C. Tokheim, Roger L. *Digital Electronics.* New York: McGraw-Hill, 1979.

BINARY LOGIC
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Logic — Principles of circuit element connections; also the circuits themselves

B. Logic gate — Circuit that produces specific binary outputs based on inputs

C. High input — Logic 1

D. Low input — Logic 0

E. Positive logic — Logic system in which the more positive voltage signifies binary 1

F. Truth table — Table that gives all the possible input combinations to a logic gate; precise method of describing how a circuit will work

EXAMPLE: A • B • C truth table (Table 1)

TABLE 1

A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

G. Boolean expression — Language used in digital electronics to show logic operation

INFORMATION SHEET

H. Complement — Binary opposite of a number or term

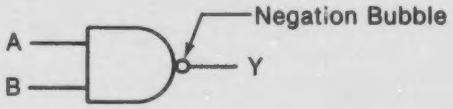
EXAMPLE: The complement of 1 would be 0, the complement of A would be $\overline{A}$.

(NOTE: Other terms that refer to complements are *inverted* and *negated*.)

I. Negation bubble — Small circle on the input or output of a logic symbol to represent an invert function (Figure 1)

EXAMPLE:

FIGURE 1



J. Universal gate — Logic gate that can be used in any combination to achieve any common logic function

EXAMPLES: NAND gate, NOR gate

K. Combinational logic circuit — Circuit using more than one logic gate to achieve a logic function

II. Symbols and abbreviations associated with binary logic

(NOTE: Symbols for specific logic gates are covered later.)

A. • — Symbol used to signify the AND Boolean expression.

EXAMPLE: A • B, which is read as *A AND B*.

B. + — Symbol used to signify the OR Boolean expression

EXAMPLE: A + B, which is read as *A OR B*.

C. $\overline{}$ — Symbol put above a letter in order to designate a NOT or complemented signal

EXAMPLES: $\overline{A}$, which is read as *not A*.
$\overline{A + B}$, which is read as *not (A OR B)*.

D. $\overline{\overline{}}$ — Symbol put above a letter in order to designate a double complement

EXAMPLE: $\overline{\overline{A}} = A$, which is read as *A double-complemented equals A*.

INFORMATION SHEET

E. $\oplus$ — Symbol used to signify the exclusive OR function

F. LED — Light emitting diode

G. Gnd — Ground potential

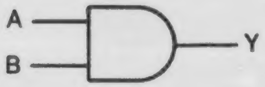
H. IC — Integrated circuit

III. Representations of logic gates (Transparency #1)

A. AND gate

1. English expression — Requires a logic 1 at all inputs to receive logic 1 output at Y
2. Boolean expression — A • B = Y
3. Logic symbol (Figure 2)

FIGURE 2



4. Truth table (Table 2)

TABLE 2

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

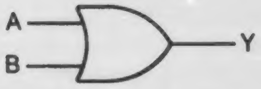
B. OR gate

1. English expression — Requires a logic 1 at any or all inputs to receive a logic 1 output at Y
2. Boolean expression — A + B = Y

INFORMATION SHEET

3. Logic symbol (Figure 3)

FIGURE 3



4. Truth table (Table 3)

TABLE 3

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

C. NOT gate

(NOTE: This gate is referred to as an *inverter.*)

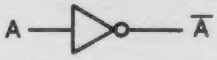
1. English expression — Requires a logic 0 input to receive a logic 1 output

   (NOTE: The output signal is the complement of the input signal.)

2. Boolean expression — $A = \overline{A}$

3. Logic symbol (Figure 4)

FIGURE 4



INFORMATION SHEET

4. Truth table (Table 4)

TABLE 4

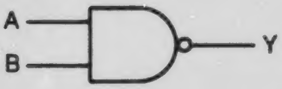
A	Y
0	1
1	0

D. NAND gate

(NOTE: This gate is referred to as a *NOT-AND* or an *inverted AND* gate.)

1. English expression — Requires a logic 0 at any or all inputs to receive a logic 1 output at Y
2. Boolean expression — $A \cdot B = \overline{Y}$ (or $\overline{A \cdot B} = Y$)
3. Logic symbol (Figure 5)

FIGURE 5



4. Truth table (Table 5)

TABLE 5

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

E. NOR gate

(NOTE: This gate is referred to as a *NOT-OR* gate.)

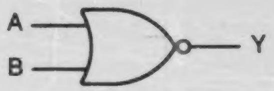
1. English expression — Requires a logic 0 at all inputs to receive a logic 1 output at Y

INFORMATION SHEET

2. Boolean expression — $A + B = \overline{Y}$ (or $\overline{A + B} = Y$)

3. Logic symbol (Figure 6)

FIGURE 6



4. Truth table (Table 6)

TABLE 6

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

F. XOR gate (exclusive OR gate)

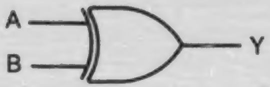
(NOTE: The XOR gate is referred to as an *any-but-not-all* gate.)

1. English expression — Requires a logic 1 at any input, but not all inputs, to receive a logic 1 output

2. Boolean expression — $A \oplus B = Y$

3. Logic symbol (Figure 7)

FIGURE 7



INFORMATION SHEET

4. Truth table (Table 7)

TABLE 7

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

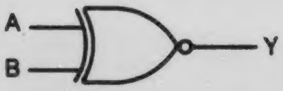
G. XNOR gate (exclusive NOR gate)

1. English expression — Requires a logic 1 at all inputs or a logic 0 at all inputs to receive a logic 1 output

2. Boolean expression — $\overline{A \oplus B} = Y$ (or $A \oplus B = \overline{Y}$)

3. Logic symbol (Figure 8)

FIGURE 8



4. Truth table (Table 8)

TABLE 8

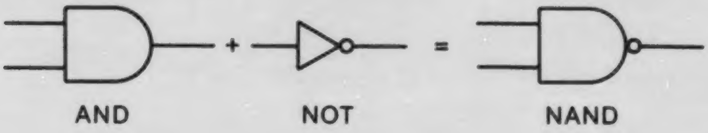
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

INFORMATION SHEET

IV. Equivalent gates for various inverted gates (Figures 9-12, Transparencies #2-#4.)

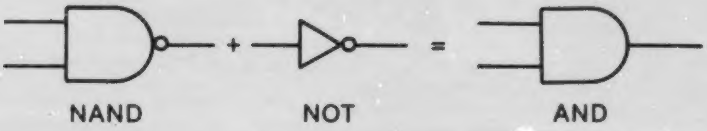
A. NAND

FIGURE 9


+
=
AND
NOT
NAND

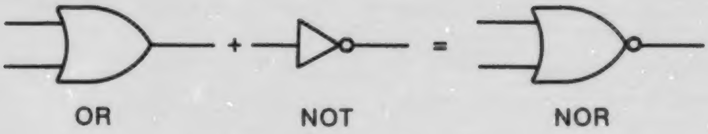
B. AND

FIGURE 10


+
=
NAND
NOT
AND

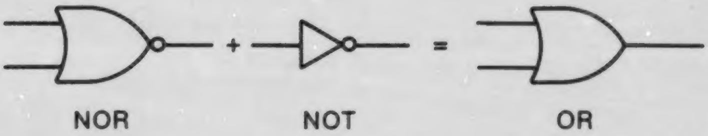
C. NOR

FIGURE 11



D. OR

FIGURE 12



INFORMATION SHEET

V. Constructing logic circuit diagrams from Boolean expressions (Transparency #5)

A. Determine the Boolean expression to be constructed

EXAMPLE: $(A \cdot B \cdot C) + (\overline{A \cdot B}) = Y$

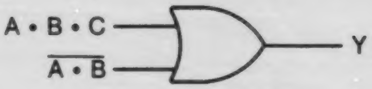
B. Simplify the Boolean expression by combining similar expressions if possible

EXAMPLE: $(A \cdot B) \cdot (C \cdot D) + (A \cdot B) = Y$
can be simplified to
$(A \cdot B \cdot C \cdot D) + (A \cdot B) = Y$

C. Determine the gate needed in order to form the output

EXAMPLE: For the Boolean expression $(A \cdot B \cdot C) + (\overline{A \cdot B}) = Y$, an OR gate is required (Figure 13).

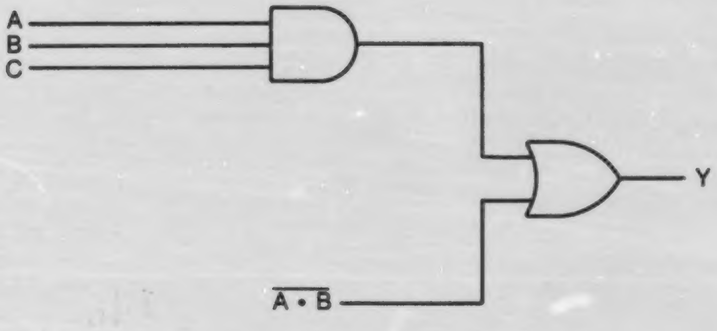
FIGURE 13



D. Determine the gate needed in order to form the first input term

EXAMPLE: For the expression $(A \cdot B \cdot C) + (\overline{A \cdot B}) = Y$
an AND gate must be added for the A • B • C input (Figure 14)

FIGURE 14

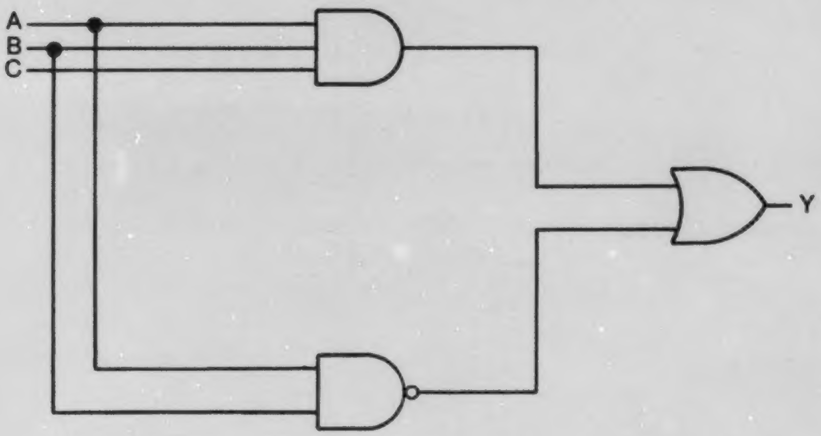


INFORMATION SHEET

E. Determine other gates needed in order to form the remaining input terms

EXAMPLE: An AND gate must again be added for the $\overline{A \cdot B}$ input (Figure 15)

FIGURE 15

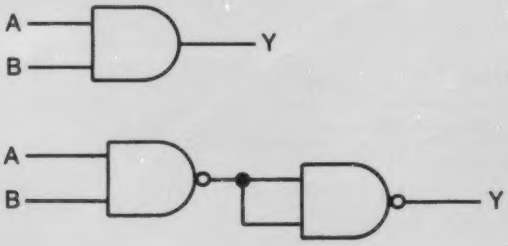


(NOTE: Truth tables may be used to verify output.)

VI. Logic gates and their equivalent NAND gate circuits (Figures 16-21)

A. AND gate

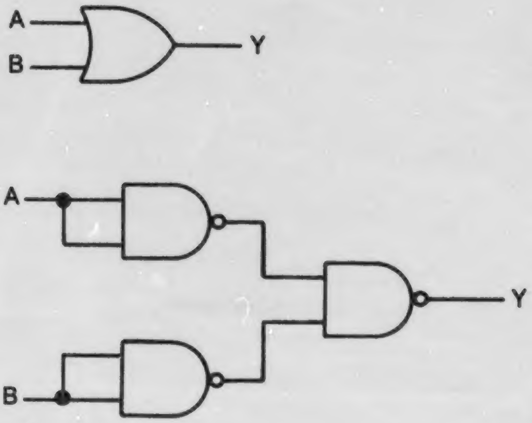
FIGURE 16



INFORMATION SHEET

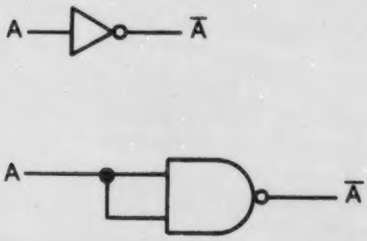
B. OR gate

FIGURE 17



C. NOT gate

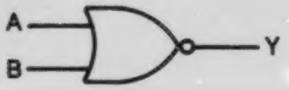
FIGURE 18

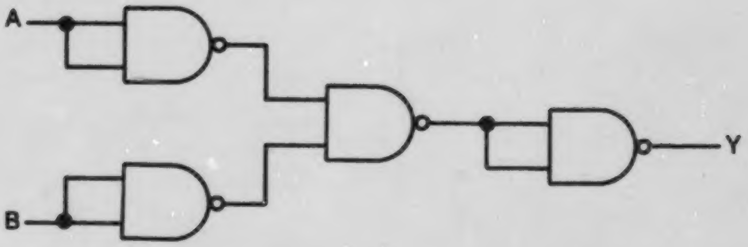


INFORMATION SHEET

D. **NOR gate**

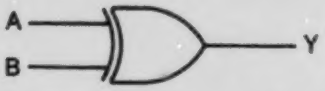
FIGURE 19

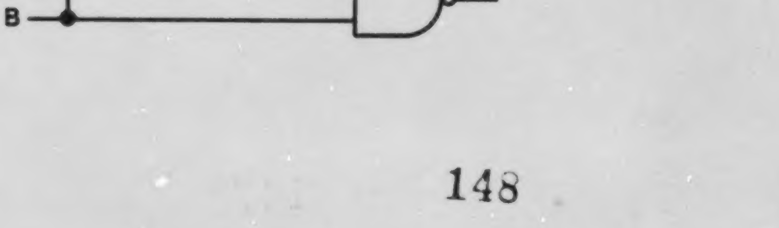




E. **XOR gate**

FIGURE 20

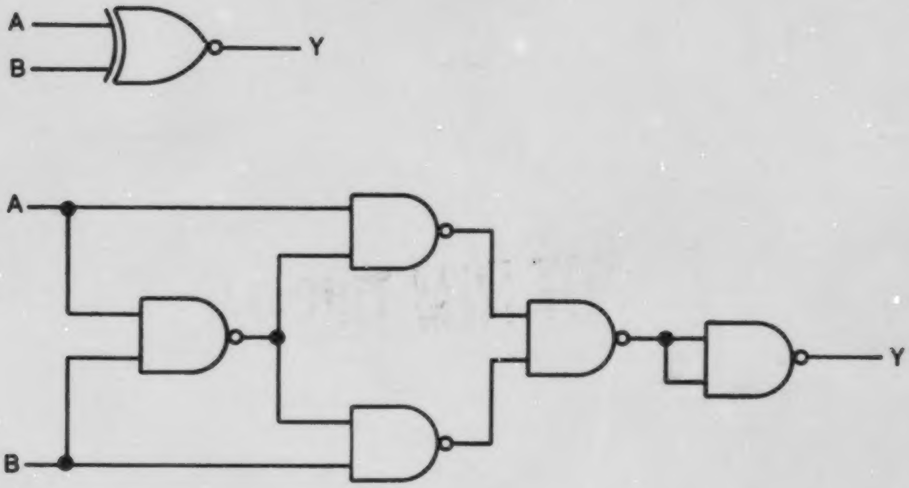




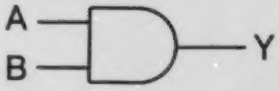
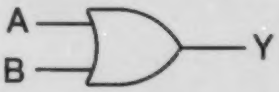
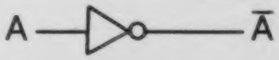
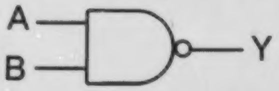
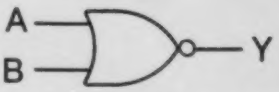
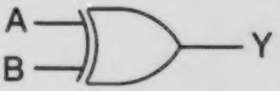
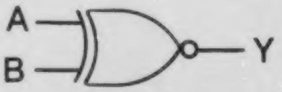
INFORMATION SHEET

F. XNOR gate

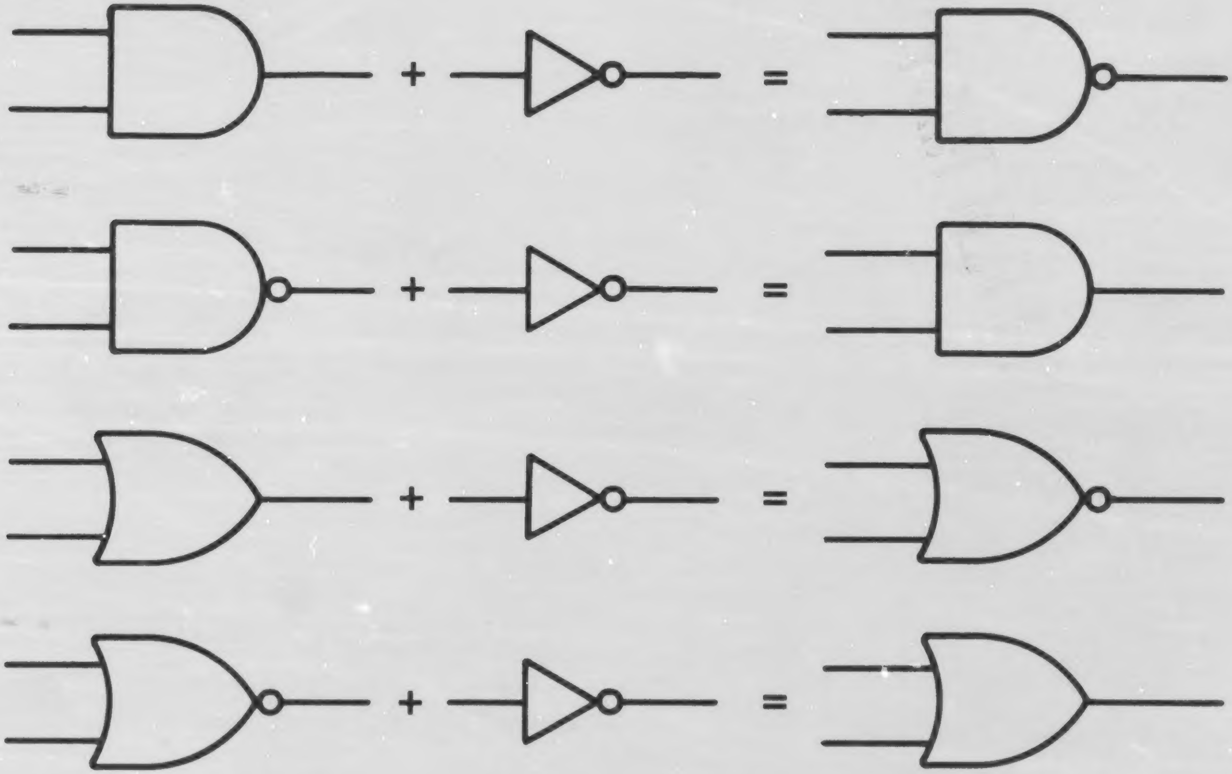
FIGURE 21



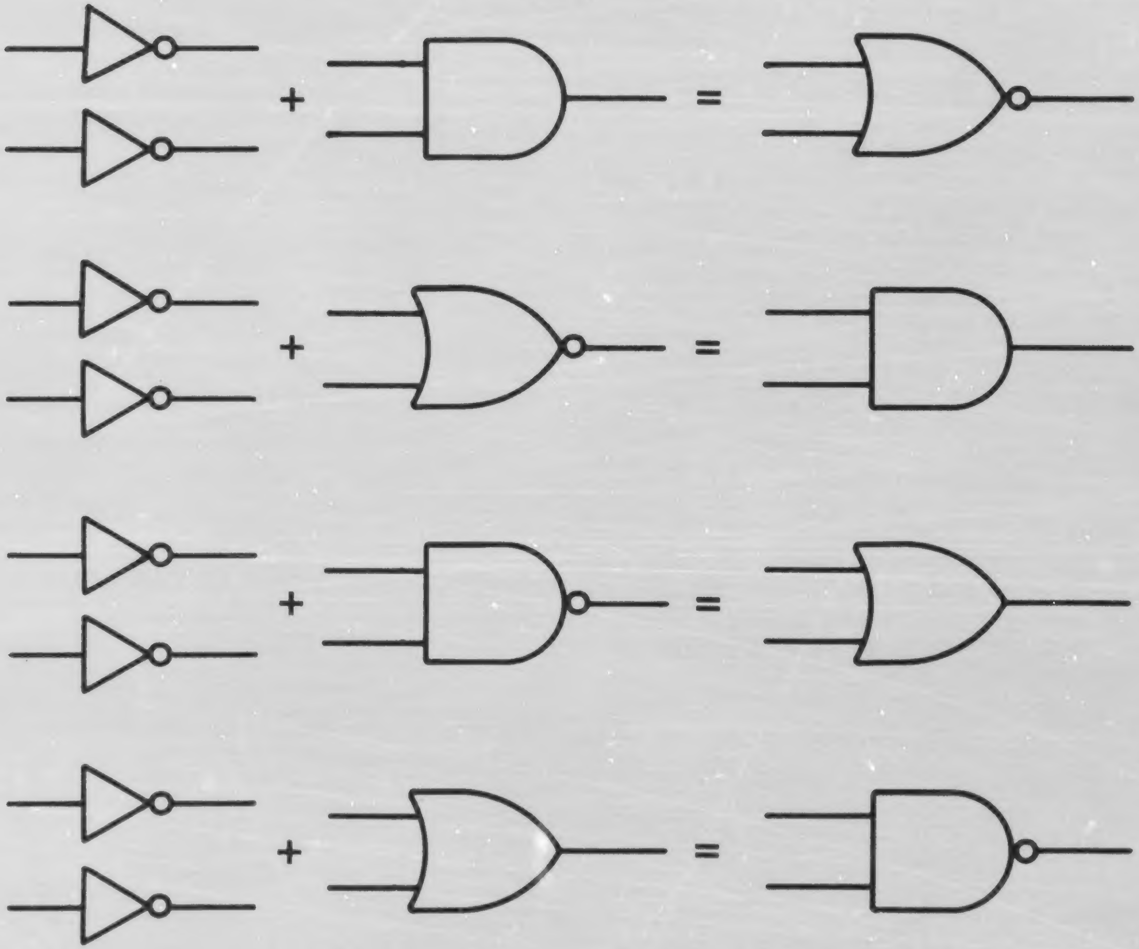
Basic Logic Gates

Logic Function	Logic Symbol	Boolean Expression	Truth Table		
			Input		Output
			A	B	Y
AND		$A \bullet B = Y$	0	0	0
			0	1	0
			1	0	0
			1	1	1
OR		$A + B = Y$	0	0	0
			0	1	1
			1	0	1
			1	1	1
NOT		$A = \overline{A}$	0	1	1
			1	1	0
NAND		$\overline{A \bullet B} = Y$ or $A \bullet B = \overline{Y}$	0	0	1
			0	1	1
			1	0	1
			1	1	0
NOR		$\overline{A + B} = Y$ or $A + B = \overline{Y}$	0	0	1
			0	1	0
			1	0	0
			1	1	0
XOR		$A \oplus B = Y$	0	0	0
			0	1	1
			1	0	1
			1	1	0
XNOR		$\overline{A \oplus B} = Y$ or $A \oplus B = \overline{Y}$	0	0	1
			0	1	0
			1	0	0
			1	1	1

Negated Circuit Outputs



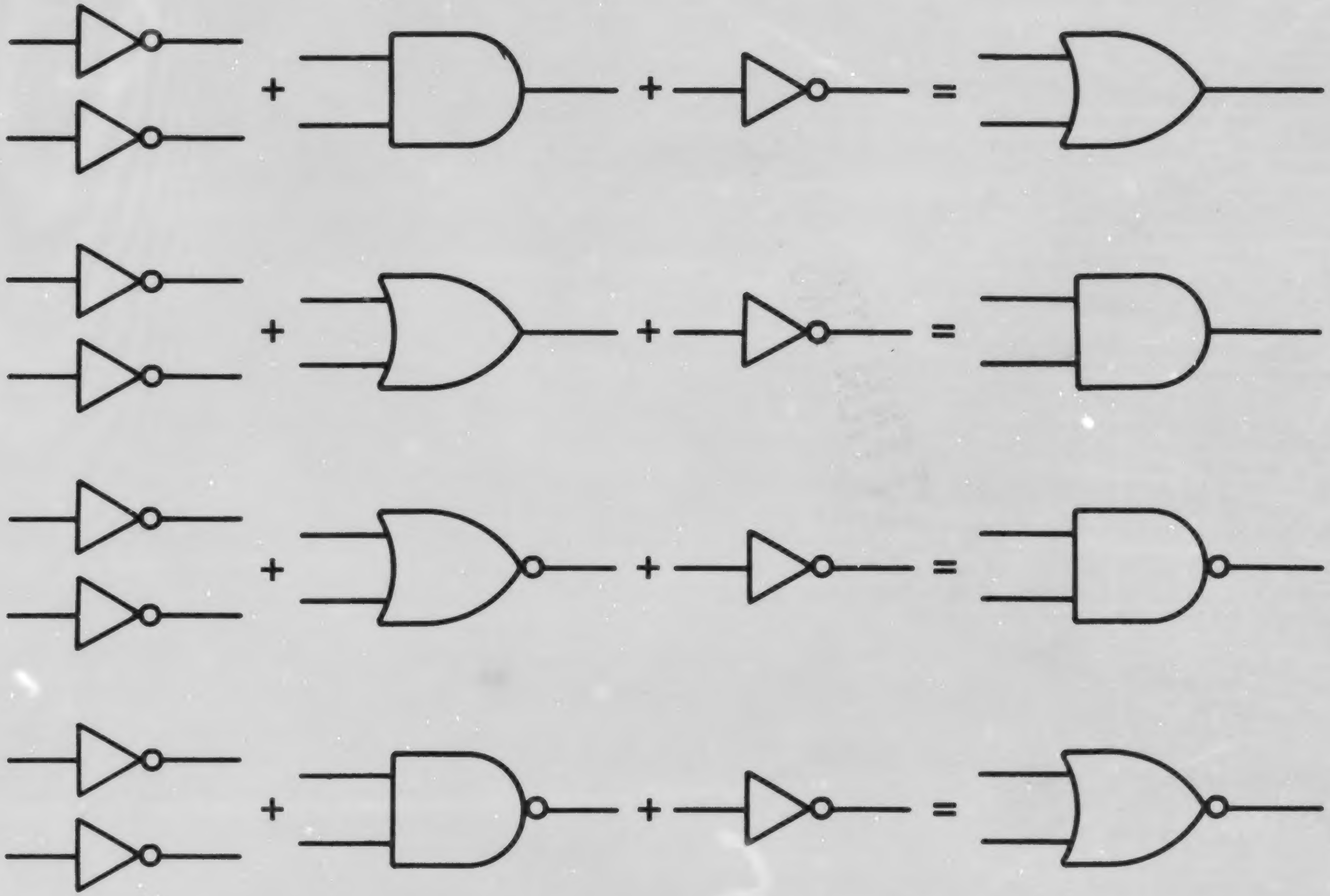
Negating Inputs



TM #3

AIE - 47-B

Negating Inputs and Outputs



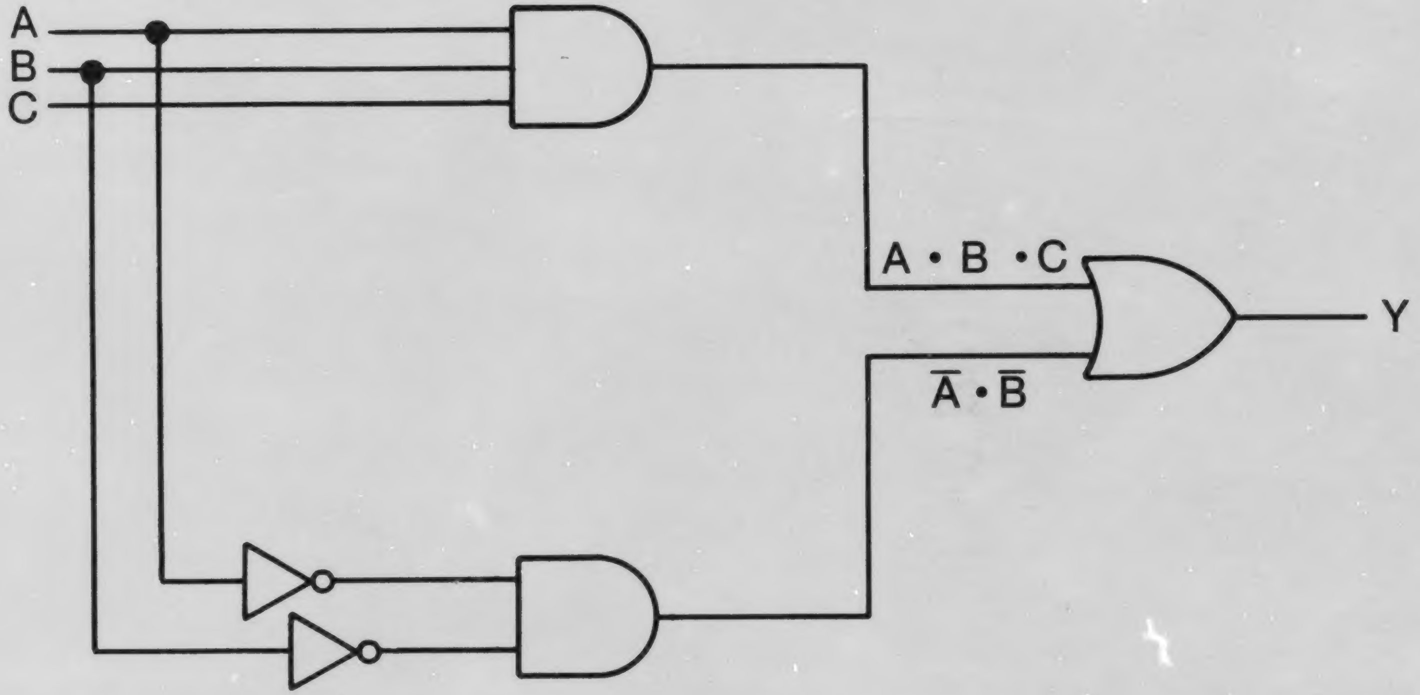
TM #4

AIE - 49-B

Logic Circuit Construction

Boolean Equation—

$(A \cdot B \cdot C) + (\overline{A} \cdot \overline{B}) = Y$


A
B
C
A • B • C
$\overline{A} \cdot \overline{B}$
Y

TM #5

157

158

AIE - 51-B

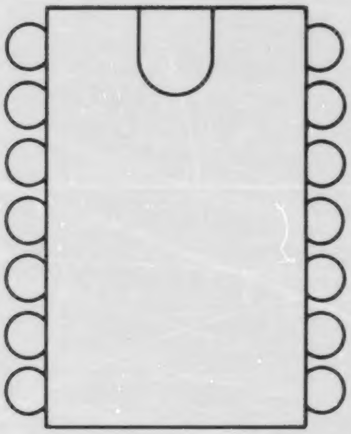
BINARY LOGIC
UNIT II

ASSIGNMENT SHEET #1 — IDENTIFY INTEGRATED CIRCUIT PIN CONFIGURATIONS

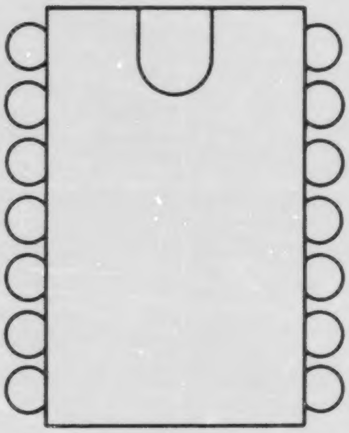
NAME ________________________________ SCORE ______________

Electronic technicians must learn to locate solid-state devices through the use of data manuals and other available resources. This information is often necessary for troubleshooting and maintenance of digital circuits.

Using the following diagrams, indicate the function of the integrated circuit; number and label the pins.

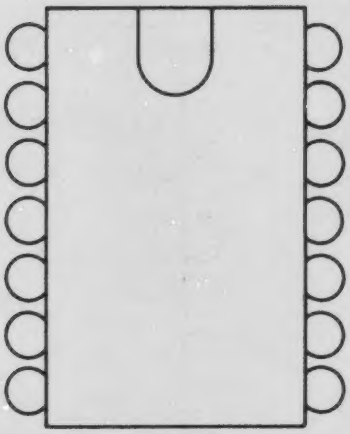


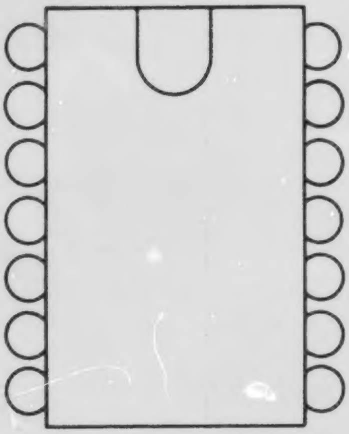
A. 7400 ____________________



B. 7402 ____________________

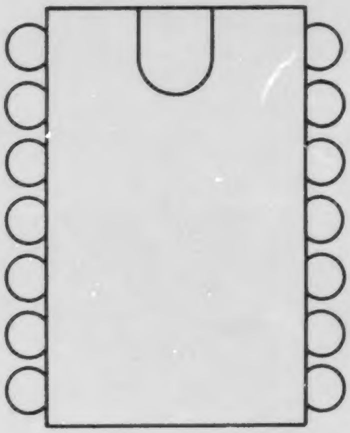
ASSIGNMENT SHEET #1

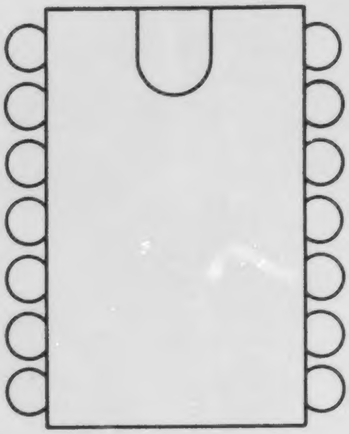




C. 7404 ______________________

D. 7408 ______________________

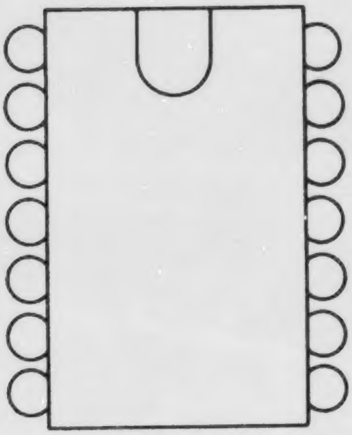




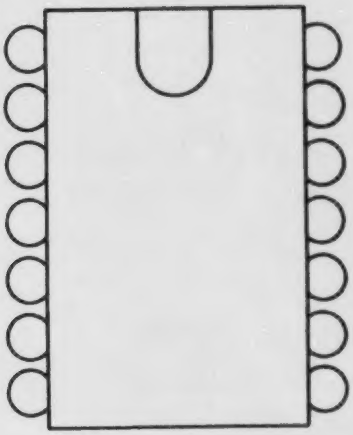
E. 7410 ______________________

F. 7420 ______________________

ASSIGNMENT SHEET #1



G. 7432 ______________________________



H. 7486 ______________________________

BINARY LOGIC
UNIT II

ASSIGNMENT SHEET #2 — CONSTRUCT LOGIC CIRCUIT DIAGRAMS FROM BOOLEAN EQUATIONS

NAME ____________________________________ SCORE ________________

As an electronics technician, you may on occasion need to construct logic circuits from Boolean equations.

Draw logic circuit diagrams for each of the following Boolean expressions.

A. $(A \cdot \overline{B} \cdot C) + (A \cdot B \cdot \overline{C}) = Y$

B. $(A \cdot B \cdot C) + (\overline{A} \cdot \overline{C}) = Y$

ASSIGNMENT SHEET #2

C. $(A \cdot \overline{C}) + (\overline{B} \cdot C) = Y$

D. $(A + B + C) \cdot (\overline{A} + \overline{B} + \overline{C}) = Y$

E. $(A + B) \cdot (\overline{B} + \overline{C}) = Y$

ASSIGNMENT SHEET #2

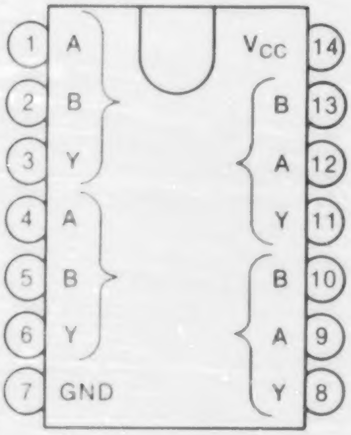
F. $(A \cdot \overline{B} \cdot C) + (\overline{A} \cdot B \cdot \overline{C}) = Y$

BINARY LOGIC
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

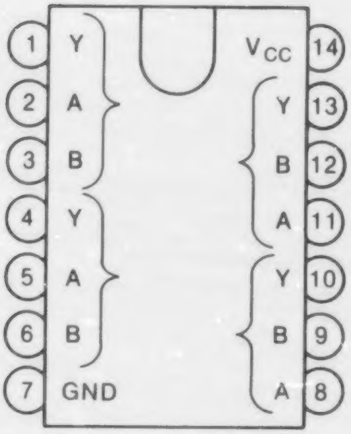
Assignment Sheet #1

A.


1 A
2 B
3 Y
4 A
5 B
6 Y
7 GND
V_{CC} 14
B 13
A 12
Y 11
B 10
A 9
Y 8

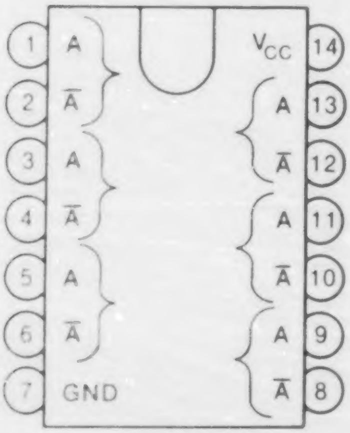
7400 Quad two-input NAND

B.


1 Y
2 A
3 B
4 Y
5 A
6 B
7 GND
V_{CC} 14
Y 13
B 12
A 11
Y 10
B 9
A 8

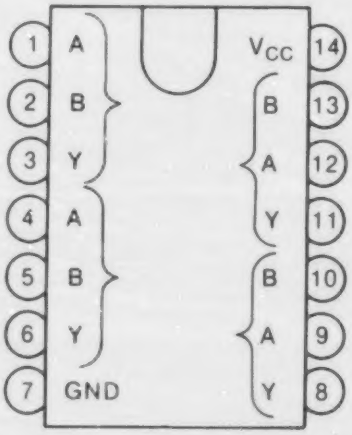
7402 Quad two-input NOR

C.


1 A
2 $\overline{A}$
3 A
4 $\overline{A}$
5 A
6 $\overline{A}$
7 GND
V_{CC} 14
A 13
$\overline{A}$ 12
A 11
$\overline{A}$ 10
A 9
$\overline{A}$ 8

7404 Hex inverter

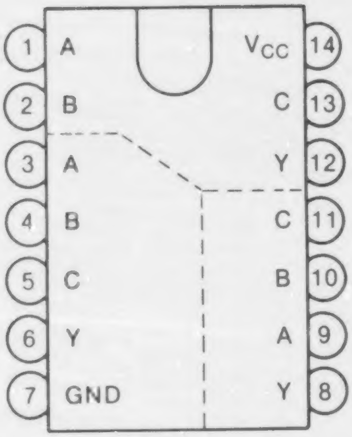
D.


1 A
2 B
3 Y
4 A
5 B
6 Y
7 GND
V_{CC} 14
B 13
A 12
Y 11
B 10
A 9
Y 8

7408 Quad two-input AND

ANSWERS TO ASSIGNMENT SHEETS

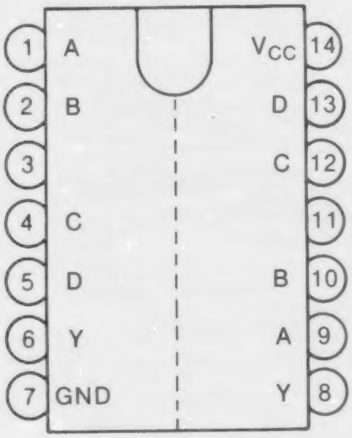
E.



1 A
VCC 14
2 B
C 13
3 A
Y 12
4 B
C 11
5 C
B 10
6 Y
A 9
7 GND
Y 8

7410 Triple three-input NAND

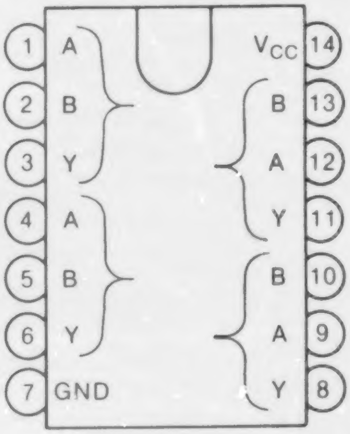
F.



1 A
VCC 14
2 B
D 13
3
C 12
4 C
11
5 D
B 10
6 Y
A 9
7 GND
Y 8

7420 Dual four-input NAND

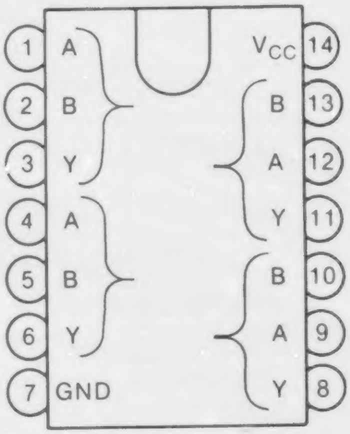
G.



1 A
VCC 14
2 B
B 13
3 Y
A 12
4 A
Y 11
5 B
B 10
6 Y
A 9
7 GND
Y 8

7432 Quad two-input OR

H.



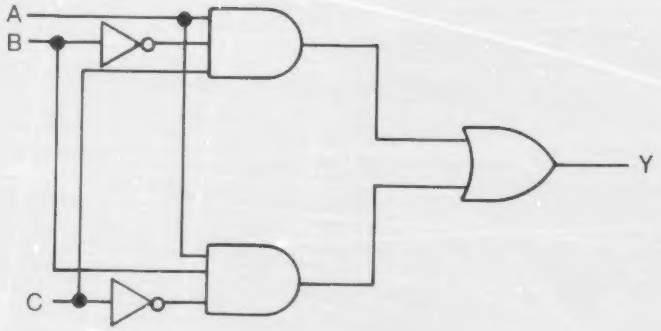
1 A
VCC 14
2 B
B 13
3 Y
A 12
4 A
Y 11
5 B
B 10
6 Y
A 9
7 GND
Y 8

7486 Quad two-input XOR

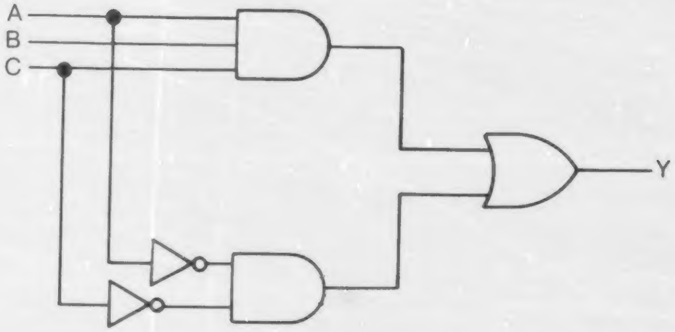
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #2

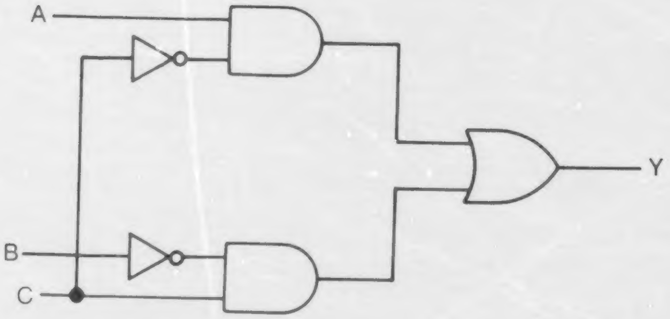
A.



B.

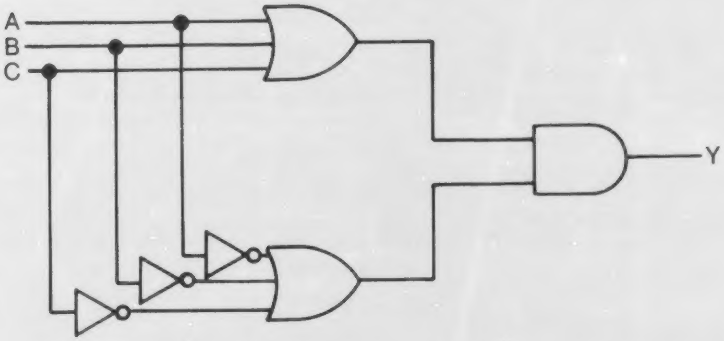


C.

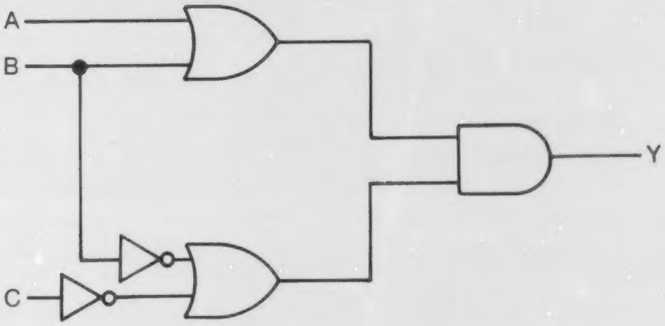


ANSWERS TO ASSIGNMENT SHEETS

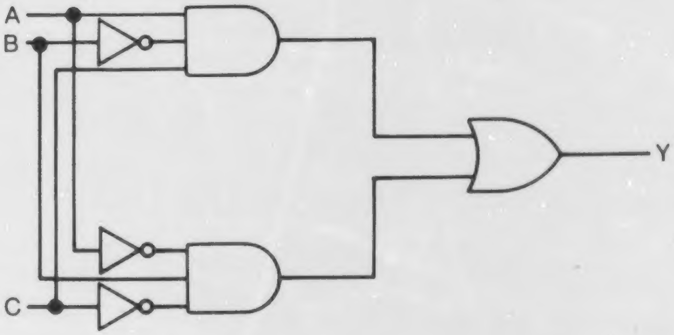
D.



E.



F.



BINARY LOGIC
UNIT II

JOB SHEET #1 — OBSERVE THE OPERATION OF *AND* GATES

I. Equipment and materials

- A. DC power supply, 5 VDC regulated
- B. LED
- C. Resistor, 150 ohm
- D. Breadboard
- E. Four SPST switches

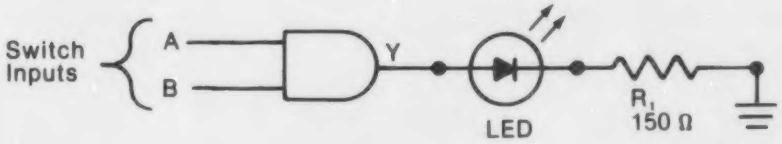
  (NOTE: A digital trainer may be used if it is equipped with the above components.)

- F. Circuit wiring
- G. Quad two-input AND gate, #7408

II. Procedure

- A. Construct circuit #1 (a two-input AND circuit) as shown in Figure 22

FIGURE 22



(NOTE: Be sure to connect the V_{CC} and ground.)

- B. Turn on power

JOB SHEET #1

C. Position the input switches to each combination shown in Table 9

(NOTE: One means on; zero means off.)

D. Record the output in the spaces provided in Table 9

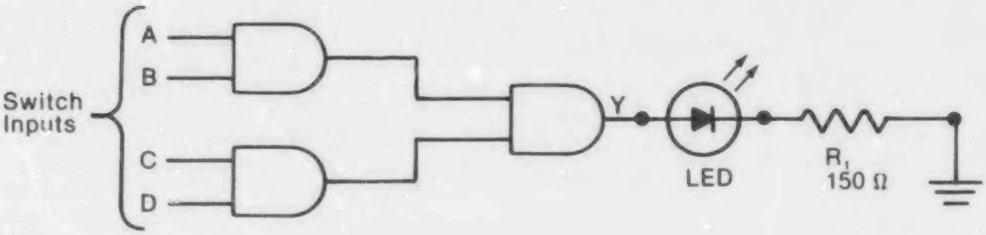
TABLE 9

Input		Output	
A	B	Light	Binary
0	0		
0	1		
1	0		
1	1		

E. Turn off power

F. Construct circuit #2 (Figure 23)

FIGURE 23



G. Turn on power

JOB SHEET #1

H. Position the input switches to each combination shown in Table 10

I. Record the output in the spaces provided in Table 10

TABLE 10

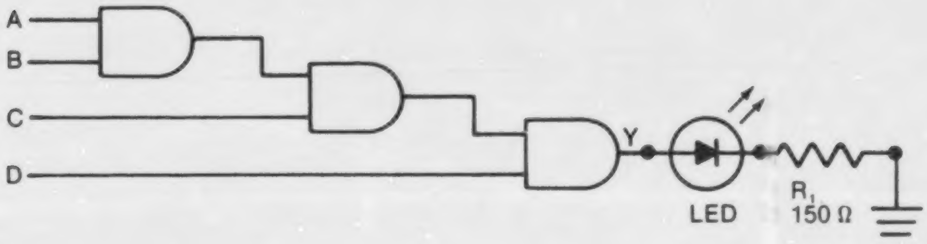
Input				Output	
A	B	C	D	Light	Binary
0	0	0	0		
0	0	0	1		
0	0	1	0		
0	0	1	1		
0	1	0	0		
0	1	0	1		
0	1	1	0		
0	1	1	1		
1	0	0	0		
1	0	0	1		
1	0	1	0		
1	0	1	1		
1	1	0	0		
1	1	0	1		
1	1	1	0		
1	1	1	1		

J. Turn off power

JOB SHEET #1

K. Construct circuit #3 (Figure 24)

FIGURE 24


A
B
C
D
Y
LED
R_1
150 Ω

L. Turn on power

JOB SHEET #1

M. Position the input switches to each combination shown in Table 11

N. Record the output in the spaces provided in Table 11

TABLE 11

Input				Output	
A	B	C	D	Light	Binary
0	0	0	0		
0	0	0	1		
0	0	1	0		
0	0	1	1		
0	1	0	0		
0	1	0	1		
0	1	1	0		
0	1	1	1		
1	0	0	0		
1	0	0	1		
1	0	1	0		
1	0	1	1		
1	1	0	0		
1	1	0	1		
1	1	1	0		
1	1	1	1		

O. Turn off power

P. Do circuit #2 and circuit #3 both have the same output?____________

(NOTE: If their truth tables do not compare, check over your work. If you cannot find the problem, consult your instructor.)

Q. Are circuit #2 and circuit #3 both the same according to their Boolean equations?____________

(NOTE: Have your instructor check your results.)

R. Put equipment and materials away

BINARY LOGIC
UNIT II

JOB SHEET #2 — OBSERVE THE OPERATION OF *OR* GATES

I. Equipment and materials

A. DC power supply, 5 VDC regulated

B. LED

C. Resistor, 150 ohm

D. Breadboard

E. Four SPST switches

(NOTE: A digital trainer may be used if it is equipped with the above components.)

F. Circuit wiring

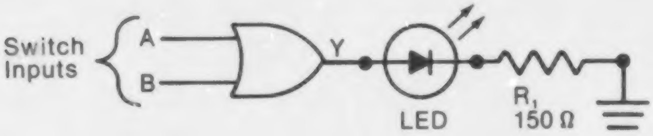
G. Quad two-input OR gate, #7432

II. Procedure

A. Construct the circuit shown in Figure 25

(NOTE: Be sure to connect the V_{CC} and ground.)

FIGURE 25



B. Turn on power

JOB SHEET #2

C. Apply the inputs indicated in Table 12

D. Record the output in the spaces provided in Table 12

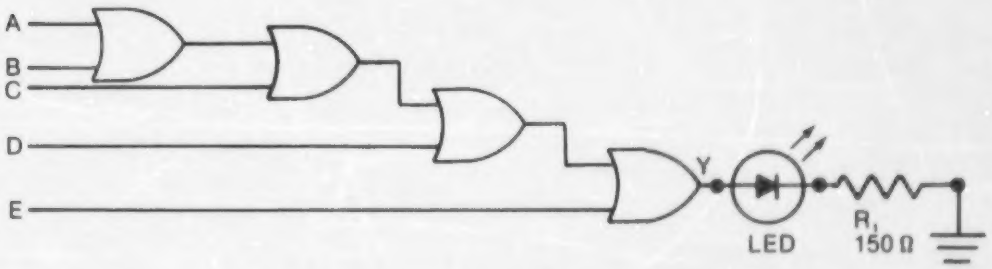
TABLE 12

Input		Output	
A	B	Light	Binary
0	0		
0	1		
1	0		
1	1		

E. Turn off power

F. Construct the circuit shown in Figure 26

FIGURE 26



(NOTE: Have the instructor check your circuit before continuing.)

G. Turn on power

H. Position the input switches to each combination shown in Table 13

JOB SHEET #2

I. Record the out[illegible] in the spaces provided in Table 13

TABLE 13

Input					Output	
A	B	C	D	E	Light	Binary
0	0	0	0	0		
0	0	0	0	1		
0	0	0	1	0		
0	0	0	1	1		
0	0	1	0	0		
0	0	1	0	1		
0	0	1	1	0		
0	0	1	1	1		
0	1	0	0	0		
0	1	0	0	1		
0	1	0	1	0		
0	1	0	1	1		
0	1	1	0	0		
0	1	1	0	1		
0	1	1	1	0		
0	1	1	1	1		
1	0	0	0	0		
1	0	0	0	1		
1	0	0	1	0		
1	0	0	1	1		
1	0	1	0	0		
1	0	1	0	1		
1	0	1	1	0		
1	0	1	1	1		
1	1	0	0	0		
1	1	0	0	1		
1	1	0	1	0		
1	1	0	1	1		
1	1	1	0	0		
1	1	1	0	1		
1	1	1	1	0		
1	1	1	1	1		

JOB SHEET #2

J. Turn off power

(NOTE: Have the instructor check your results and discuss any problems that may have occurred during the project.)

K. Put equipment and materials away

BINARY LOGIC
UNIT II

JOB SHEET #3 — OBSERVE THE OPERATION OF *NOT* GATES

I. Equipment and materials

A. DC power supply, 5 VDC regulated

B. Five LEDs

C. Resistor, 150 ohm

D. Breadboard

E. Two switches

(NOTE: A digital trainer may be used if it is equipped with the above components.)

F. Circuit wire

G. Hex inverter, #7404

H. Quad two-input AND gate, #7408

I. Quad two-input OR gate, #7402

J. Quad two-input NAND gate, #7400

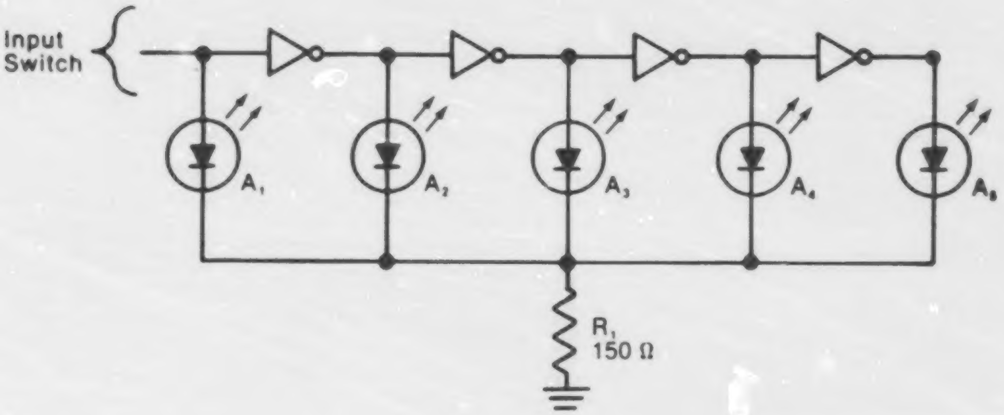
K. Quad two-input NOR gate, #7402

JOB SHEET #3

II. Procedure

A. Construct the inverter circuit (circuit #1) shown in Figure 27

FIGURE 27


Input Switch
A1
A2
A3
A4
A5
R1
150 Ω

B. Turn on power

C. Position the input switches to each combination shown in Table 14

D. Record the outputs in the spaces provided in Table 14

TABLE 14

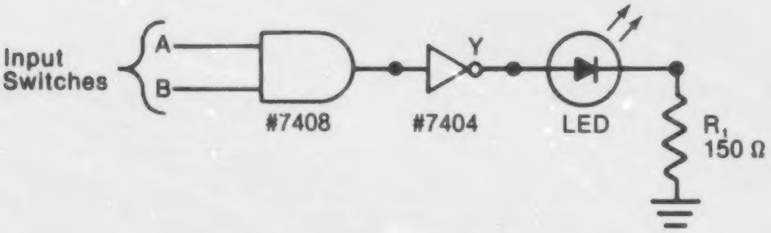
Input	A_1	A_2	A_3	A_4	A_5
0					
1					

E. Turn off power

JOB SHEET #3

F. Construct circuit #2 (Figure 28)

FIGURE 28


Input Switches
A
B
#7408
Y
#7404
LED
R, 150 Ω

G. Turn on power

H. Position the input switches as shown in Table 15

I. Record output in the spaces provided in Table 15

TABLE 15

Input		Output	
A	B	Light	Binary
0	0		
0	1		
1	0		
1	1		

J. Turn off power

K. What gate circuit is equivalent to circuit #2?________________________

JOB SHEET #3

L. Draw the equivalent circuit below, including the LED

M. Construct circuit #3 as you have drawn it

N. Turn on power

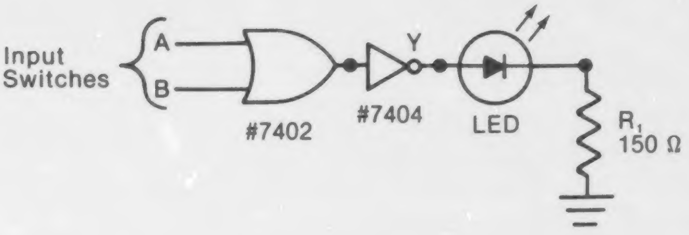
O. Position the switches as shown in Table 17 and compare the output

P. Record results ______________________________

Q. Turn off power

R. Construct circuit #4 (Figure 29)

FIGURE 29


Input Switches
A
B
#7402
Y
#7404
LED
R₁
150 Ω

S. Turn on power

JOB SHEET #3

T. Position the input switches as shown in Table 16

U. Record the output in the spaces provided in Table 16

TABLE 16

Input		Output	
A	B	Light	Binary
0	0		
0	1		
1	0		
1	1		

V. Turn off power

W. What gate circuit is equivalent to circuit #4? ____________________

(NOTE: Check your results with the instructor.)

X. Put equipment and materials away

BINARY LOGIC
UNIT II

JOB SHEET #4 — OBSERVE THE OPERATION OF EXCLUSIVE *OR* GATES

I. Equipment and materials

A. DC power supply, 5 VDC regulated

B. LED

C. Resistor, 150 ohm

D. Breadboard

E. Two SPST switches

(NOTE: A digital trainer may be used if it is equipped with the above components.)

F. Circuit wires

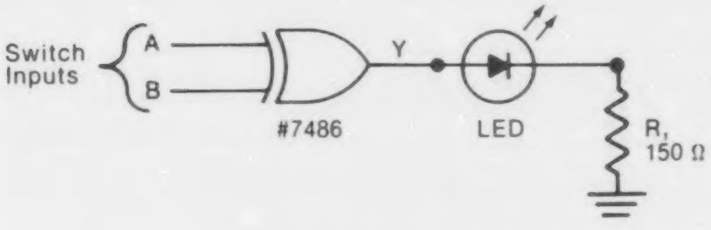
G. Exclusive OR gate, #7486

H. Hex inverter, #7404

II. Procedure

A. Construct the circuit shown in Figure 30

FIGURE 30



B. What type circuit is this?______________________________

C. Turn on power

JOB SHEET #4

D. Position the input switches to each combination shown in Table 17

E. Record the output in the spaces provided in Table 17

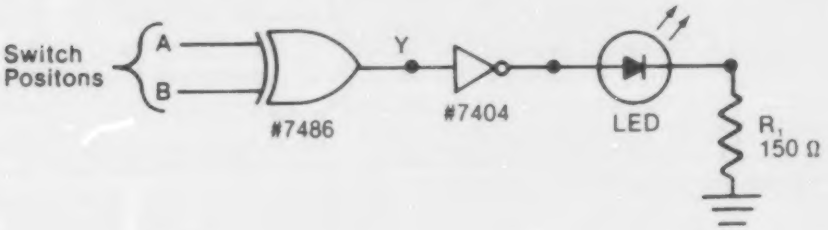
TABLE 17

Input		Output	
A	B	Light	Binary
0	0		
0	1		
1	0		
1	1		

F. Turn off power

G. Construct the circuit shown in Figure 31

FIGURE 31


Switch Positons
A
B
#7486
Y
#7404
LED
R₁
150 Ω

H. What type circuit is this?______________________________________

I. Turn on power

J. Position the input switches to each combination shown in Table 18

JOB SHEET #4

K. Record the output in the spaces provided in Table 18

TABLE 18

Input		Output	
A	B	Light	Binary
0	0		
0	1		
1	0		
1	1		

L. Turn off power

(NOTE: Have your instructor check your results.)

M. Put equipment and materials away

BINARY LOGIC
UNIT II

JOB SHEET #5 — OBSERVE OPERATION OF *NAND* GATES IN VARIOUS CONFIGURATIONS

I. Equipment and materials

A. DC power supply, 5 VDC regulated

B. LED

C. Resistor, 150 ohm

D. Breadboard

E. Two SPST switches

(NOTE: A digital trainer may be used if it is equipped with the above components.)

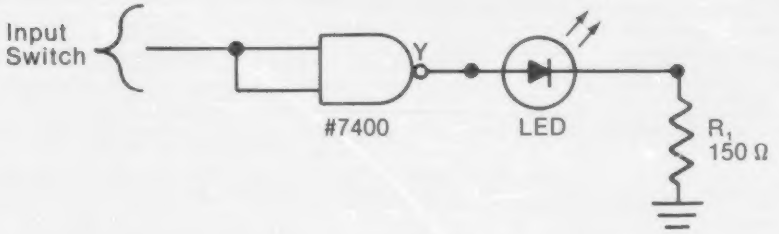
F. Circuit wiring

G. Two quad two-input NAND gates, #7400

II. Procedure

A. Construct the circuit shown in Figure 32

FIGURE 32



B. Turn on power

JOB SHEET #5

C. Position the input switch as shown in Table 19

D. Record the output in the spaces provided in Table 19

TABLE 19

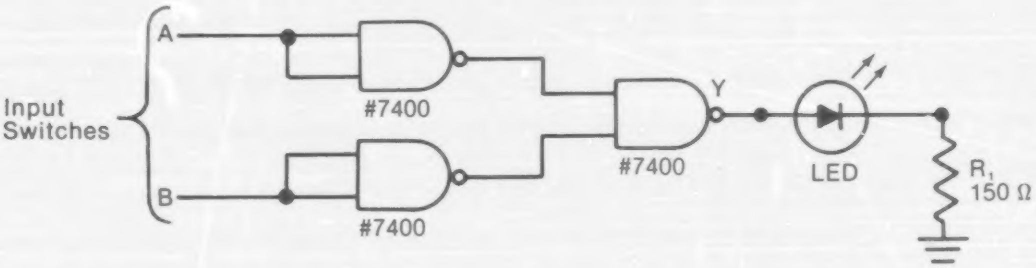
Input	Output	
A	Light	Binary
0		
1		

E. Turn off power

F. What type gate does the above circuit represent?____________________

G. Construct the circuit shown in Figure 33

FIGURE 33



H. Turn on power

I. Position the input switches in the positions shown in Table 20

J. Record the output in the spaces provided in Table 20

TABLE 20

Input		Output	
A	B	Light	Binary
0	0		
0	1		
1	0		
1	1		

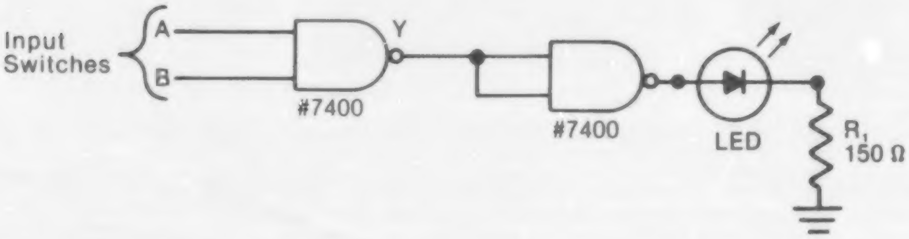
JOB SHEET #5

K. Turn off power

L. What type gate does the above circuit represent?____________________

M. Construct the circuit shown in Figure 34

FIGURE 34



N. Turn on power

O. Position the input switches to each combination shown in Table 21

P. Record the output in the spaces provided in Table 21

TABLE 21

Input		Output	
A	B	Light	Binary
0	0		
0	1		
1	0		
1	1		

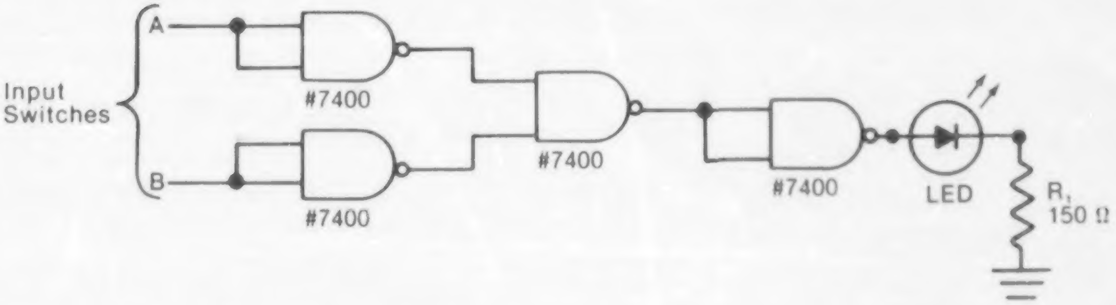
Q. Turn off power

R. What type gate does the above circuit represent?____________________

JOB SHEET #5

S. Construct the circuit as shown in Figure 35

FIGURE 35


A
B
Input Switches
#7400
#7400
#7400
#7400
LED
R, 150 Ω

T. Turn on power

U. Position the input switches as shown in Table 22

V. Record the outputs in the spaces provided in Table 22

TABLE 22

Input		Output	
A	B	Light	Binary
0	0		
0	1		
1	0		
1	1		

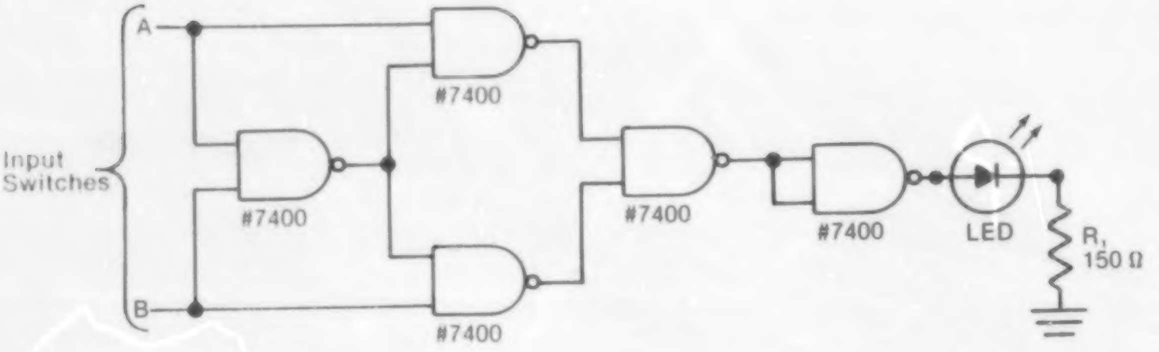
W. Turn off power

X. What type gate does the above circuit represent?____________________

JOB SHEET #5

Y. Construct the circuit shown in Figure 36

FIGURE 36


A
B
Input Switches
#7400
#7400
#7400
#7400
#7400
LED
R, 150 Ω

Z. Turn on power

AA. Position the input switches in the positions shown in Table 23

BB. Record the outputs in the spaces provided in Table 23

TABLE 23

Input		Output	
A	B	Light	Binary
0	0		
0	1		
1	0		
1	1		

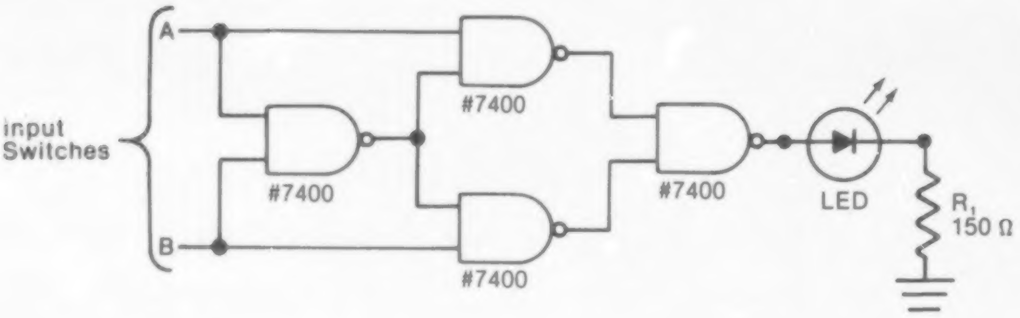
CC. Turn off power

DD. What type gate does the above circuit represent?____________________

JOB SHEET #5

EE. Construct the circuit shown in Figure 37

FIGURE 37


A
B
input Switches
#7400
#7400
#7400
#7400
LED
R
150 Ω

FF. Turn on power

GG. Position the input switches in the positions shown in Table 24; record the outputs in the spaces provided

TABLE 24

Input		Output	
A	B	Light	Binary
0	0		
0	1		
1	0		
1	1		

HH. Turn off power

II. What type gate does the above circuit represent?____________________

(NOTE: Have your instructor check your results.)

JJ. Put equipment and materials away

BINARY LOGIC
UNIT II

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with binary logic to their correct definitions. Write the correct numbers in the blanks.

_____a. Logic 0

_____b. Circuit using more than one logic gate to achieve a logic function

_____c. Principles of circuit element connections; also the circuits themselves

_____d. Binary opposite of a number or term

_____e. Table that gives all possible input combinations to a logic gate; precise method of describing how a circuit will work

_____f. Logic 1

_____g. Logic gate that can be used in any combination to achieve any common logic function

_____h. Language used in digital electronics to show logic operation

_____i. Small circle on the input or output of a logic symbol to represent an invert function

_____j. Circuit that produces specific binary outputs based on inputs

_____k. Logic system in which the more positive voltage signifies binary 1

1. Logic
2. Logic gate
3. High input
4. Low input
5. Positive logic
6. Truth table
7. Boolean expression
8. Complement
9. Negation bubble
10. Universal gate
11. Combinational logic circuit

2. Match abbreviations and symbols associated with binary logic to their correct definitions. Write the correct numbers in the blanks. Abbreviations and symbols are continued on the next page.

_____a. Symbol used to signify the exclusive OR function

_____b. Integrated circuit

1. •
2. +

TEST

______c. Ground potential

______d. Symbol used to signify the AND Boolean expression

______e. Symbol used to signify the OR Boolean expression

______f. Symbol put above a letter in order to designate a NOT or complemented signal

______g. Light emitting diode

______h. Symbol put above a letter in order to designate a double complement

3. $\overline{}$
4. $\overline{\overline{}}$
5. $\oplus$
6. LED
7. Gnd
8. IC

3. Distinguish among representations of logic gates. Write AND, OR, NOT, NAND, NOR, XOR, or XNOR in the blanks before the appropriate gates.

______a. Requires a logic 0 at any or all inputs to receive a logic 1 output at Y

______b. Requires a logic 1 at all inputs to receive a logic 1 output at Y

______c. Requires a logic 1 at all inputs or a logic 0 at all inputs to receive a logic 1 output

______d. Requires a logic 0 at all inputs to receive a logic 1 output at Y

______e. Requires a logic 1 at any input, but not all inputs, to receive a logic 1 output

______f. Requires a logic 1 at any or all inputs to receive a logic 1 output at Y

______g. Requires a logic 0 input to receive a logic 1 output

______h. $\overline{A \oplus B} = Y$

______i. $A + B = Y$

______j. $A = \overline{A}$

______k. $A \bullet B = Y$

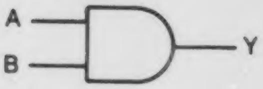
______l. $A \oplus B = Y$

______m. $A \bullet B = \overline{Y}$

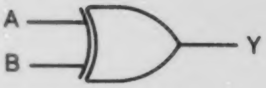
______n. $A + B = \overline{Y}$

TEST

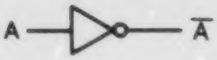
______o.



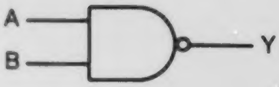
______p.



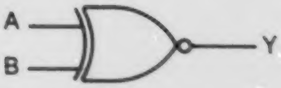
______q.



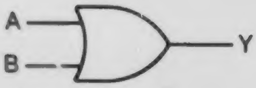
______r.



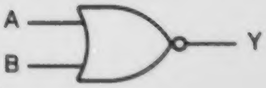
______s.



______t.



______u.



______v.

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

TEST

______w.

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

______x.

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

______y.

A	Y
0	1
1	0

______z.

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

______aa.

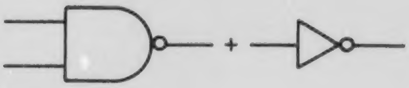
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

______bb.

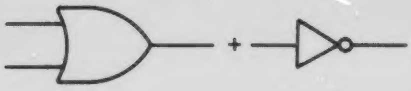
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

4. Identify equivalent gates for various inverted gates. Write the correct names in the blanks.

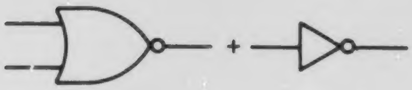
AND
OR
NOR
NAND



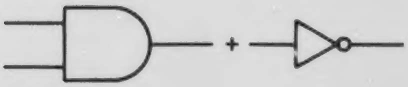
a. ______________________________



b. ____________________



c. ____________________



d. ____________________

5. Construct logic circuit diagrams from the following Boolean expressions.

   a. $(\overline{A} + \overline{B}) \cdot (A + B + C) = Y$

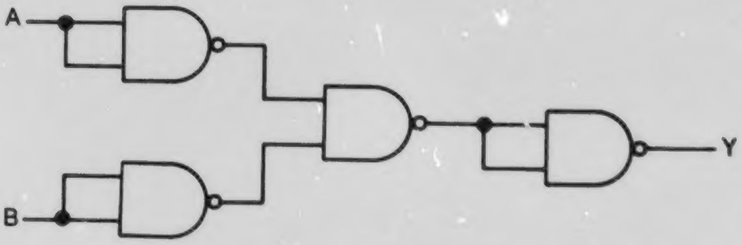
TEST

b. $(A \cdot B \cdot \overline{C}) + (\overline{A} \cdot B \cdot \overline{C}) = Y$

c. $(A \cdot B) + (A \cdot \overline{C}) + (A \cdot \overline{B}) = Y$

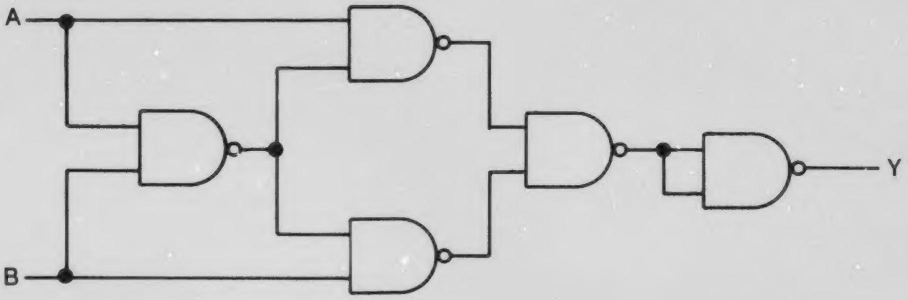
6. Identify equivalent NAND circuits for various logic gates. Write the correct names in the blanks.

AND gate	**NOR gate**
OR gate	**XOR gate**
NOT gate	**XNOR gate**

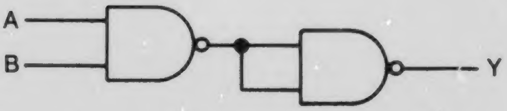


a. ______________________________

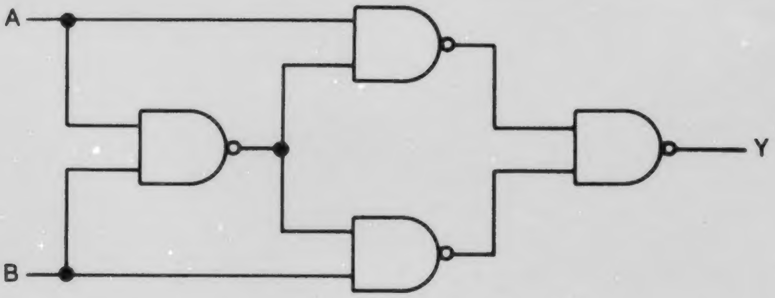
TEST



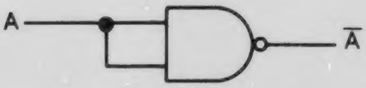
b. ______________________________



c. ______________________________

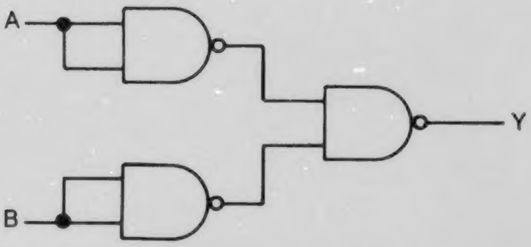


d. ______________________________


A
$\overline{A}$

e. ______________________________

TEST



f. ______________________________

(NOTE: Test questions 7 and 8 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

7. Identify integrated circuit pin configurations.

8. Demonstrate the ability to

   a. Observe the operation of AND gates.

   b. Observe the operation of OR gates.

   c. Observe the operation of NOT gates.

   d. Observe the operation of exclusive OR gates.

   e. Observe the operation of NAND gates in various configurations.

BINARY LOGIC
UNIT II

ANSWERS TO TEST

1.	a.	4	g.	10
	b.	11	h.	7
	c.	1	i.	9
	d.	8	j.	2
	e.	6	k.	5
	f.	3		

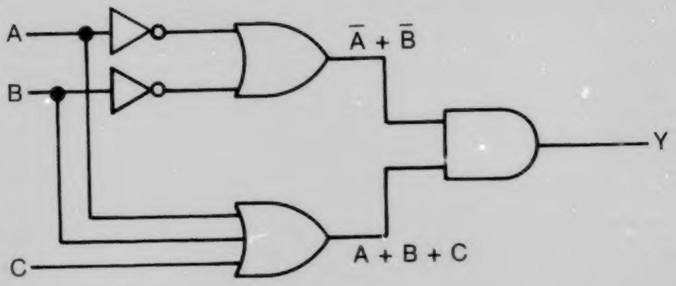
2.	a.	5	e.	2
	b.	8	f.	3
	c.	7	g.	6
	d.	1	h.	4

3.	a.	NAND	h.	XNOR	o.	AND	v.	NOR
	b.	AND	i.	OR	p.	XOR	w.	NAND
	c.	XNOR	j.	NOT	q.	NOT	x.	XOR
	d.	NOR	k.	AND	r.	NAND	y.	NOT
	e.	XOR	l.	XOR	s.	XNOR	z.	AND
	f.	OR	m.	NAND	t.	OR	aa.	XNOR
	g.	NOT	n.	NOR	u.	NOR	bb.	OR

4.	a.	AND
	b.	NOR
	c.	OR
	d.	NAND

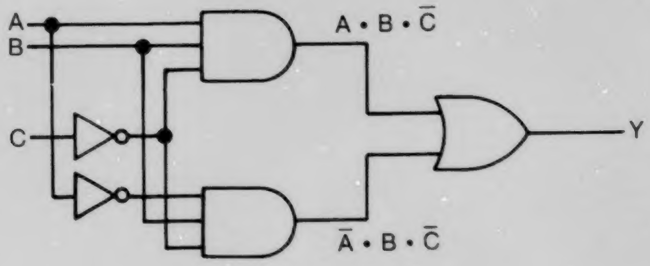
ANSWERS TO TEST

5. a.



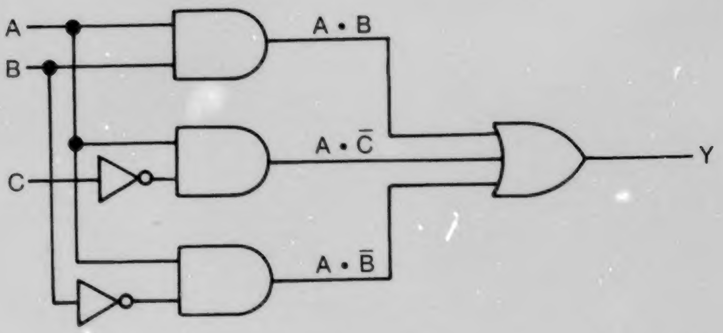
A
B
C
$\overline{A} + \overline{B}$
A + B + C
Y

b.



A
B
C
$A \cdot B \cdot \overline{C}$
$\overline{A} \cdot B \cdot \overline{C}$
Y

c.



A
B
C
$A \cdot B$
$A \cdot \overline{C}$
$A \cdot \overline{B}$
Y

6. a. NOR gate

b. XNOR gate

ANSWERS TO TEST

c. AND gate

d. XOR gate

e. NOT gate

f. OR gate

7. Evaluated to the satisfaction of the instructor

8. Performance skills evaluated to the satisfaction of the instructor

BINARY CODES
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to convert numbers to binary codes used in digital and microelectronics. The student will show this knowledge by completing the assignment sheet and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with binary codes to their correct definitions.
2. Convert decimal numbers to 8421 binary coded decimal numbers.
3. Convert 8421 binary coded decimal numbers to decimal numbers.
4. Convert hexadecimal numbers to binary coded hexadecimal numbers.
5. Convert binary coded hexadecimal numbers to hexadecimal numbers.

BINARY CODES
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Provide students with objective sheet.

   B. Provide students with information and assignment sheets.

   C. Make transparency.

   D. Discuss unit and specific objectives.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment sheet.

   G. Show students examples of how various codes may be used in digital electronics and microcomputers.

   H. Give test.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency master: TM #1 — Code Table

   E. Assignment Sheet #1 — Convert Various Decimal and BCD Codes

   F. Answers to assignment sheet

   G. Test

   H. Answers to test

III. Unit references

   A. Kaufman, Milton, and J. A. Wilson. *Electronics Technology.* New York: McGraw Hill, 1982.

   B. Malvino, Albert P., and Donald P. Leach. *Digital Principles and Applications*, 2nd ed. New York: McGraw Hill, 1975.

   C. Tokheim, Roger L. *Digital Electronics*. New York: McGraw Hill, 1979.

BINARY CODES
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Binary coded decimal (BCD) — Binary code in which each decimal digit is expressed by a group of four binary digits

(NOTE: The 8421 BCD, the code in which four binary digits are used with respective values of 8, 4, 2, and 1, is the most commonly used BCD code in digital electronics; but other BCD codes do exist.)

B. Hexadecimal number system — Numbering system that uses the numerals 0 through 9 and the letters A through F, thus having a base of 16

C. Binary coded hexadecimal (BCH) — Binary code in which each hexadecimal digit is expressed by a group of four binary digits

(NOTE: There are other binary numbering systems, such as binary coded octal, which uses the numerals 0 through 7. However, BCD and BCH are the most commonly used codes in electronic equipment.)

D. Binary code encoder — Device that converts a digital or analog signal to a coded form without a loss of information

E. Binary code decoder — Device that converts a binary coded number to a decimal number

F. Least significant digit (LSD) — Rightmost digit of a number, which has the lowest value

G. Most significant digit (MSD) — Leftmost digit of a number, which has the highest value

H. Complement — Binary opposite of a number

I. Digital signal — Electrical signal having definite level of amplitude that can be represented as a numeral in various coding systems

(NOTE: The simplest type of digital signal is the on-off or binary signal.)

J. Analog signal — Electrical signal that varies continuously and smoothly in amplitude as a result of generating input

EXAMPLES: Radio broadcasts and telephone line transmissions using direct signals

INFORMATION SHEET

II. Converting decimal numbers to 8421 BCD numbers — Change each decimal digit into a four-digit binary number (Table 1; Transparency #1)

(NOTE: A good practice is to begin with the LSD and convert each digit in order.)

TABLE 1

Decimal	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

EXAMPLES: Convert the decimal number 6491 to BCD.

$$\begin{tikzcd} 6 \arrow[d] & 4 \arrow[d] & 9 \arrow[d] & 1 \arrow[d] & \text{Decimal} \\ 0110 & 0100 & 1001 & 0001 & \text{BCD} \end{tikzcd}$$

Change the decimal number 108 to BCD.

$$\begin{tikzcd} 1 \arrow[d] & 0 \arrow[d] & 8 \arrow[d] & \text{Decimal} \\ 0001 & 0000 & 1000 & \text{BCD} \end{tikzcd}$$

III. Converting 8421 BCD numbers to decimal numbers

A. Separate the number into four-digit groups, beginning at the right

EXAMPLE: 0101 1001

B. Change each four-digit binary number to a decimal number

EXAMPLE: Convert the 8421 BCD number 0101 1001 to a decimal number.

$$\begin{tikzcd} 0101 \arrow[d] & 1001 \arrow[d] & \text{BCD} \\ 5 & 9 & \text{Decimal number} \end{tikzcd}$$

INFORMATION SHEET

IV. Converting a hexadecimal number to a BCH number — Change each hexadecimal digit into a four-digit binary number (Table 2; Transparency #1)

(NOTE: There are sixteen possible combinations of four binary digits. [Two to the fourth power is sixteen.] The numerals 0 through 9 are used for ten of the sixteen combinations; the remaining six are designated by the letters A through F.)

TABLE 2

Hexadecimal	**Binary**
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

EXAMPLE: Convert the hexadecimal number 69AF to BCH.

6	9	A	F	Hexadecimal
↓	↓	↓	↓	
0110	1001	1010	1111	BCH

V. Converting BCH numbers to hexadecimal numbers

A. Separate the number into four-digit groups, beginning at the right

EXAMPLE: 1100 1000 1110

B. Change each four-digit binary number into a hexadecimal number

EXAMPLES: Convert the BCH number 1100 1000 1110 into a hexadecimal number.

1100	1000	1110	BCH
↓	↓	↓	
C	8	E	Hexadecimal

Code Table

Decimal	Binary	Hexadecimal	BCD	BCH
0	000000	0	0000 0000	0000 0000
1	000001	1	0000 0001	0000 0001
2	000010	2	0000 0010	0000 0010
3	000011	3	0000 0011	0000 0011
4	000100	4	0000 0100	0000 0100
5	000101	5	0000 0101	0000 0101
6	000110	6	0000 0110	0000 0110
7	000111	7	0000 0111	0000 0111
8	001000	8	0000 1000	0000 1000
9	001001	9	0000 1001	0000 1001
10	001010	A	0001 0000	0000 1010
11	001011	B	0001 0001	0000 1011
12	001100	C	0001 0010	0000 1100
13	001101	D	0001 0011	0000 1101
14	001110	E	0001 0100	0000 1110
15	001111	F	0001 0101	0000 1111
16	010000	10	0001 0110	0001 0000
17	010001	11	0001 0111	0001 0001
18	010010	12	0001 1000	0001 0010
19	010011	13	0001 1001	0001 0011
20	010100	14	0010 0000	0001 0100
21	010101	15	0010 0001	0001 0101
22	010110	16	0010 0010	0001 0110
23	010111	17	0010 0011	0001 0111
24	011000	18	0010 0100	0001 1000
25	011001	19	0010 0101	0001 1001
26	011010	1A	0010 0110	0001 1010
27	011011	1B	0010 0111	0001 1011
28	011100	1C	0010 1000	0001 1100
29	011101	1D	0010 1001	0001 1101
30	011110	1E	0011 0000	0001 1110
31	011111	1F	0011 0001	0001 0101
32	100000	20	0011 0010	0010 0000

BINARY CODES
UNIT III

ASSIGNMENT SHEET #1 — CONVERT VARIOUS DECIMAL AND BCD CODES

NAME ______________________________ SCORE ______________

A technician must be familiar with various codes used in digital electronics and microprocessors and computers. A technician must also be familiar with conversion procedures and have an understanding of these codes.

Convert the following numbers as indicated above each group and place the correct answers in the spaces provided.

1. Convert the following decimal numbers to 8421 BCD.

    a. 2 = ____________________
    b. 6 = ____________________
    c. 10 = ____________________
    d. 18 = ____________________
    e. 31 = ____________________
    f. 342 = ____________________
    g. 406 = ____________________
    h. 900 = ____________________
    i. 1001 = ____________________
    j. 1011 = ____________________

2. Convert the following 8421 BCD numbers to decimal numbers.

    a. 1001 = ____________________
    b. 0101 = ____________________
    c. 0111 0010 = ______________
    d. 1000 0000 = ______________
    e. 0100 0001 = ______________
    f. 0110 0101 0011 = __________
    g. 1001 1001 0000 = __________
    h. 0011 0100 0010 = __________
    i. 0110 1000 0100 1001 = _____
    j. 0001 0111 0010 0011 = _____

3. Convert the following hexadecimal numbers to BCH.

    a. 0 = ____________________
    b. 2 = ____________________
    c. 5 = ____________________
    d. 10 = ____________________
    e. D = ____________________
    f. E = ____________________
    g. G = ____________________
    h. 1E = ____________________
    i. 4B = ____________________
    j. 9A = ____________________

ASSIGNMENT SHEET #1

4. Convert the following BCH numbers to hexadecimal numbers.

a. 1101 = ____________________

b. 1001 = ____________________

c. 0011 = ____________________

d. 1010 = ____________________

e. 1100 = ____________________

f. 0010 1110 = ________________

g. 0011 1111 = ________________

h. 0101 0000 = ________________

i. 0001 1001 = ________________

j. 1101 0000 = ________________

BINARY CODES
UNIT III

ANSWERS TO ASSIGNMENT SHEET

Assignment Sheet #1

1. a. 0010
   b. 0110
   c. 0001 0000
   d. 0001 1000
   e. 0011 0001
   f. 0011 0100 0010
   g. 0100 0000 0110
   h. 1001 0000 0000
   i. 0001 0000 0000 0001
   j. 0001 0000 0001 0001

2. a. 9
   b. 5
   c. 72
   d. 80
   e. 41
   f. 653
   g. 990
   h. 342
   i. 6849
   j. 1723

3. a. 0000
   b. 0010
   c. 0101
   d. 0001 0000
   e. 1101
   f. 1110
   g. G is not hexadecimal
   h. 0001 1110
   i. 0100 1011
   j. 1001 1010

4. a. D
   b. 9
   c. 3
   d. A
   e. C
   f. 2E
   g. 3F
   h. 50
   i. 19
   j. D0

BINARY CODES
UNIT III

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with binary codes to their correct definitions. Write the correct numbers in the blanks.

______a. Binary code in which each decimal digit is expressed by a group of four binary digits

______b. Device that converts a binary coded number to a decimal number

______c. Binary opposite of a number

______d. Binary code in which each hexadecimal digit is expressed by a group of four binary digits

______e. Device that converts a digital or analog signal to a coded form without a loss of information

______f. Electrical signal having definite level of amplitude that can be represented as a numeral in various coding systems

______g. Rightmost digit of a number, which has the lowest value

______h. Numbering system that uses the numerals 0 through 9 and the letters A through F, thus having a base of 16

______i. Electrical signal that varies continuously and smoothly in amplitude as a result of generating input

______j. Leftmost digit of a number, which has the highest value

1. Binary code encoder
2. Binary code decoder
3. Binary coded decimal (BCD)
4. Hexadecimal number system
5. Binary coded hexadecimal (BCH)
6. Least significant digit (LSD)
7. Most significant digit (MSD)
8. Complement
9. Analog signal
10. Digital signal

TEST

2. Convert the following decimal numbers to 8421 BCD numbers.

a. 1 = ____________________

b. 11 = ____________________

c. 42 = ____________________

d. 189 = ____________________

e. 402 = ____________________

3. Convert the following 8421 BCD numbers to decimal numbers.

a. 0000 0111 = ____________

b. 1000 0000 = ____________

c. 0011 1001 = ____________

d. 0101 1001 0110 = ____________

e. 0010 0111 0001 = ____________

4. Convert the following hexadecimal numbers to BCH numbers.

a. 3 = ____________________

b. 8 = ____________________

c. D = ____________________

d. 15 = ____________________

e. 3A = ____________________

5. Convert the following BCH numbers to hexadecimal numbers.

a. 0000 1000 = ____________

b. 0001 1100 = ____________

c. 1010 1110 = ____________

d. 0110 0000 = ____________

e. 0010 1111 = ____________

BINARY CODES
UNIT III

ANSWERS TO TEST

1.	a.	3	f.	10
	b.	2	g.	6
	c.	8	h.	4
	d.	5	i.	9
	e.	1	j.	7

2.	a.	0000 0001	d.	0001 1000 1001
	b.	0001 0001	e.	0100 0000 0010
	c.	0100 0010		

3.	a.	7	d.	596
	b.	80	e.	271
	c.	89		

4.	a.	0000 0011	d.	0001 0101
	b.	0000 1000	e.	0011 1010
	c.	0000 1101		

5.	a.	8	d.	60
	b.	1C	e.	2F
	c.	AE		

COUNTERS
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to construct and analyze various counters and other flip-flops. The student will show this knowledge by completing assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with counters to their correct definitions.
2. Distinguish among characteristics of common flip-flop circuits.
3. List ways of classifying counters.
4. Identify integrated circuit pin configurations.
5. Demonstrate the ability to
    a. Construct and analyze an R-S flip-flop.
    b. Construct and analyze a J-K flip-flop circuit.
    c. Construct and analyze a ripple counter.
    d. Construct and analyze an up/down counter.

COUNTERS
UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

A. Make transparencies.

B. Provide students with objective sheet.

C. Discuss unit and specific objectives.

D. Provide students with information, assignment, and job sheets.

E. Discuss information sheet.

F. Demonstrate and discuss procedures outlined in assignment and job sheets.

G. Display the various outputs of the flip-flop circuits through the use of a multiple channel oscilloscope, showing wave comparisons.

H. Have the students build a four-bit counter using only AND gates, NAND gates, and inverters.

I. Give test.

II. Instructional materials

A. Objective sheet

B. Information sheet

C. Transparency masters

1. TM #1 — R-S Flip-Flop
2. TM #2 — D Flip-Flop
3. TM #3 — J-K Flip-Flop
4. TM #4 — Master/Slave Flip-Flop
5. TM #5 — Master/Slave Flip-Flop Waveform
6. TM #6 — Ripple Counter (Asynchronous, Up, Binary Counter)
7. TM #7 — Down Counter (Asynchronous, Down, Binary Counter)
8. TM #8 — Synchronous Counter (Synchronous, Up, Decade Counter)

SUGGESTED ACTIVITIES

D. Assignment Sheet #1 — Identify Integrated Circuit Pin Configurations

E. Answers to assignment sheet

F. Job sheets

   1. Job Sheet #1 — Construct and Analyze an R-S Flip-Flop

   2. Job Sheet #2 — Construct and Analyze a J-K Flip-Flop Circuit

   3. Job Sheet #3 — Construct and Analyze a Ripple Counter

   4. Job Sheet #4 — Construct and Analyze an Up/Down Counter

G. Test

H. Answers to test

III. Unit references

A. Barber, Alfred W. *Practical Guide to Digital Integrated Circuits*. West Nyack, New York: Parker Publishing Co., Inc., 1976.

B. Pasahow, Edward. *Digital Integrated Circuits for Electronics Technicians*. New York: McGraw-Hill, 1979.

COUNTERS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Flip-flop circuit — Circuit that can remain in one of two positions, either low or high, and must be activated by a trigger or clock pulse; also called a *bistable multivibrator*

B. Trigger — Electronic pulse that starts an action in a circuit

C. Clock pulse — Pulse used to gate information in a digital flip-flop circuit, often called a *trigger pulse*

D. Synchronous — Controlled by equally spaced clock pulses

E. Asynchronous — Not controlled by clock pulses

F. Set — To place a storage circuit into one of two states

G. Reset — To return a storage circuit to an initial state

H. Toggle — Flip-flop circuit that changes states on each clock pulse

I. Four-bit binary counter — Counter circuit that counts through sixteen different states, or a count from 0 through 15

J. Modulo — Indication of how many states there are in a binary counter circuit

K. Ripple counter — Counter in which all the flip-flops trigger sequentially; often called a *sequential counter*

L. Decade counter — Counter that has ten stable states

M. Level-triggered counter — Counter triggered by high only or low only input

N. Edge-triggered counter — Counter triggered by any change in input

O. Allow — To place a counter into a state that permits an action to occur on the next clock pulse

(NOTE: Terms such as *set/allow* or *reset/allow* indicate that the set or the reset action places the counter in a state that will lead to a specific action for various conditions of the next clock pulse.)

INFORMATION SHEET

II. Characteristics of common flip-flop circuits

(NOTE: Flip-flop circuits are available in IC form or may be constructed using logic gates. All flip-flop circuits have two outputs, Q and $\overline{Q}$, one of which is always the complement of the other.)

A. R-S flip-flop circuit (Transparency #1)

1. Requires two data inputs, set (S) and reset (R)

2. Will not function if R and S are in the zero state at the same time

   (NOTE: Certain combinations of states in counters are impossible to achieve and are called *prohibited* states. An R-S flip-flop must receive high input on either the set or the reset, or both, to operate.)

3. Will remain in the previous state if R and S are high

B. D flip-flop circuit (Transparency #2)

1. Requires only one external data input plus a clock pulse

2. Generates the same output after a clock pulse as the input

C. J-K flip-flop circuit (Transparency #3)

(NOTE: The J-K flip-flop is one of the most widely used in industrial electronics. One J-K flip-flop is used for each bit and should be in the toggle position with both data inputs high.)

1. Requires two data inputs, J and K, plus a clock pulse

2. Is disabled and the clock pulse will not change the circuit state if both data inputs are low

3. Will change states at the next clock pulse if either data input but not both inputs, is high

4. Will change states on each clock pulse if both data inputs are high; this is called *toggling*

5. Uses a J input that is the set input and will set/allow the flip-flop on the next clock pulse *if* the input is high *and* the flip-flop is in the reset state

6. Uses a K input that is the reset input and will set the flip-flop on the next clock pulse *if* the input is high *and* the flip-flop is in the set state

INFORMATION SHEET

D. Master/slave (M/S) flip-flop (Transparencies #4 and #5)

(NOTE: The master/slave flip-flop is a combination of a positive-triggered and a negative-triggered flip-flop. The master/slave flip-flop may also be referred to as an *edge-triggered* flip-flop.)

1. Requires two data inputs, J and K, plus a clock pulse
2. Master flip-flop will change states on each positive clock pulse if both data inputs are high
3. Slave flip-flop will change states on each negative clock pulse if both data inputs are high
4. Slave flip-flop will copy the action of the master flip-flop after a delay of one clock pulse
5. Will change states on each clock pulse once the clock pulse goes high, and will continue to change states on each pulse if the clock pulse becomes low

III. Ways of classifying counters (Transparencies #6-#8)

(NOTE: Counters may be classified by the type of input required, the use of clock impulse in triggering, and by direction of counter movement.)

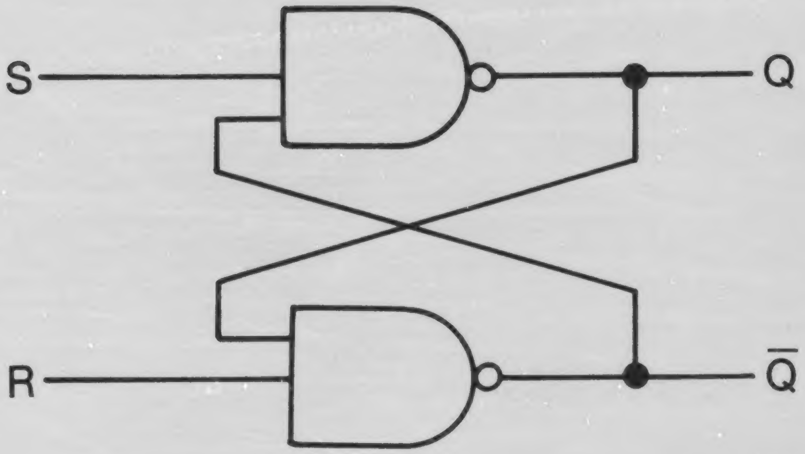
A. Up or down

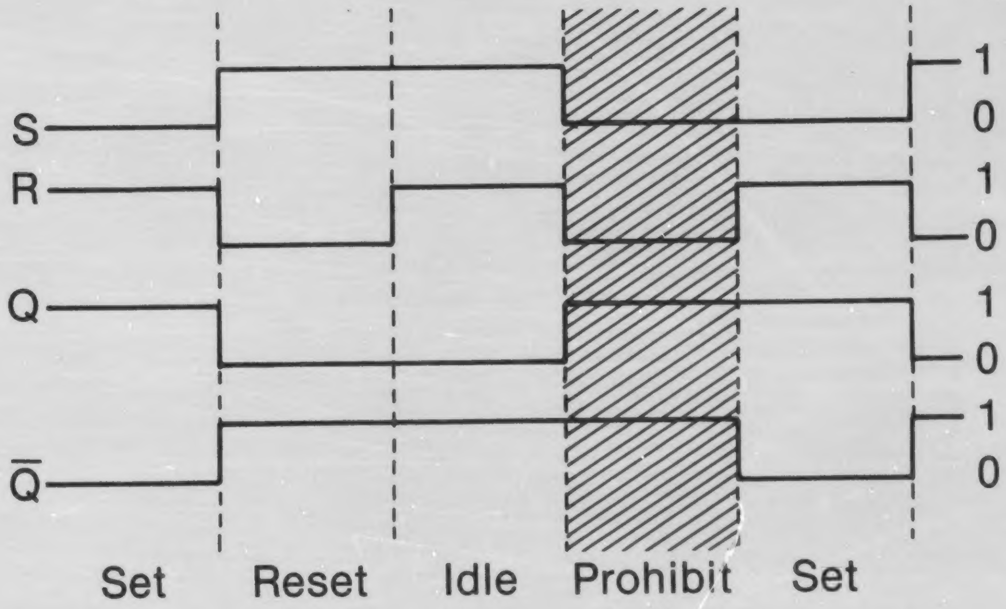
B. Decade or binary

C. Synchronous or asynchronous

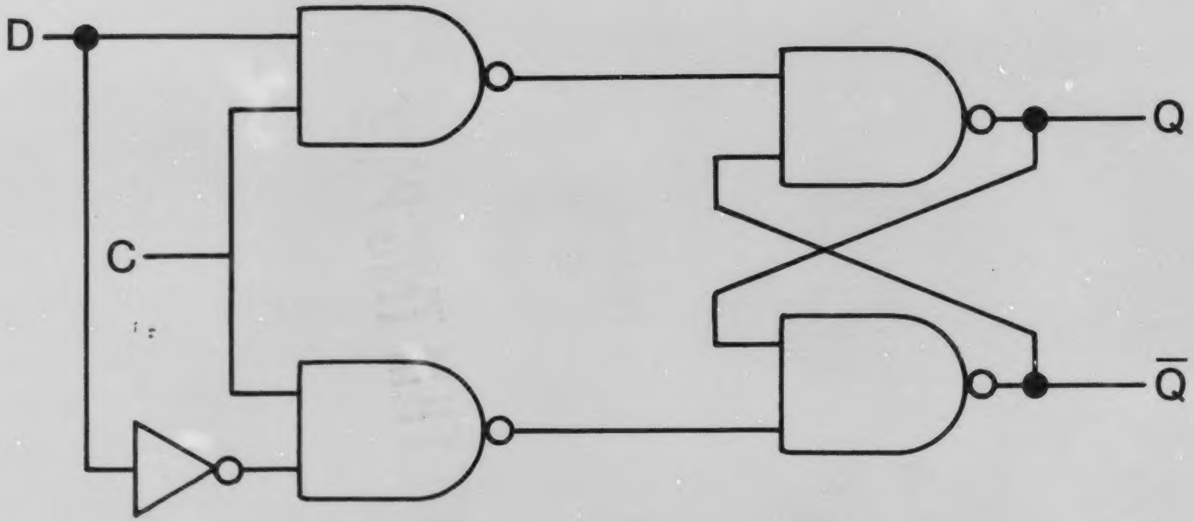
(NOTE: The D and the J-K flip-flops are all synchronous because they require a clock pulse. Flip-flops that do not require a clock input are asynchronous.)

R-S Flip-Flop

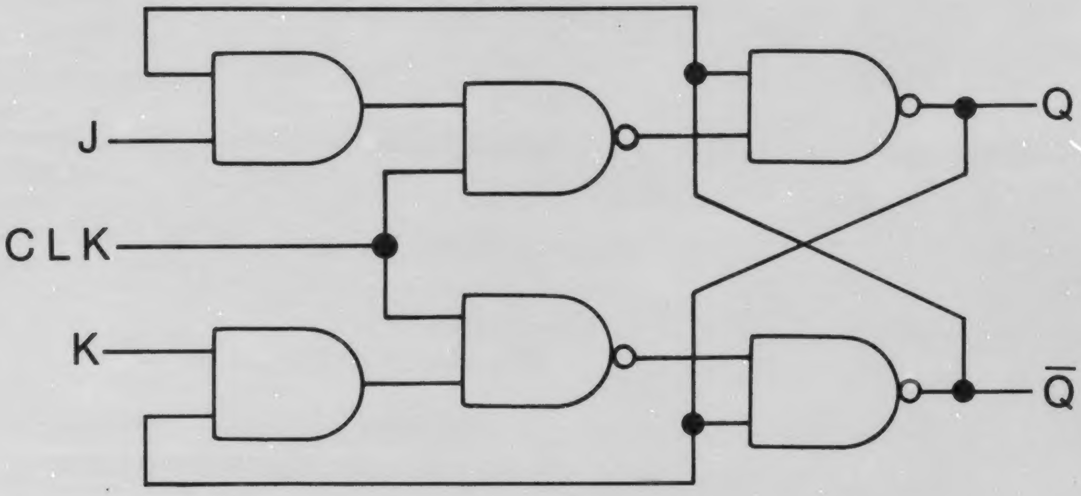

S
Q
R
$\overline{Q}$

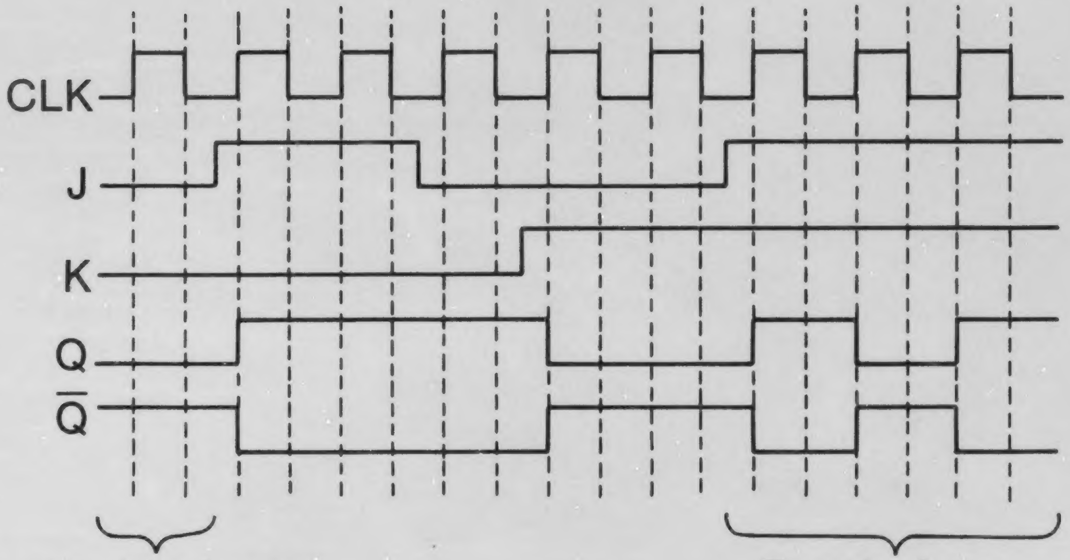

S
R
Q
$\overline{Q}$
1
0
1
0
1
0
1
0
Set
Reset
Idle
Prohibit
Set

D Flip-Flop


D
C
Q
$\overline{Q}$

J-K Flip-Flop

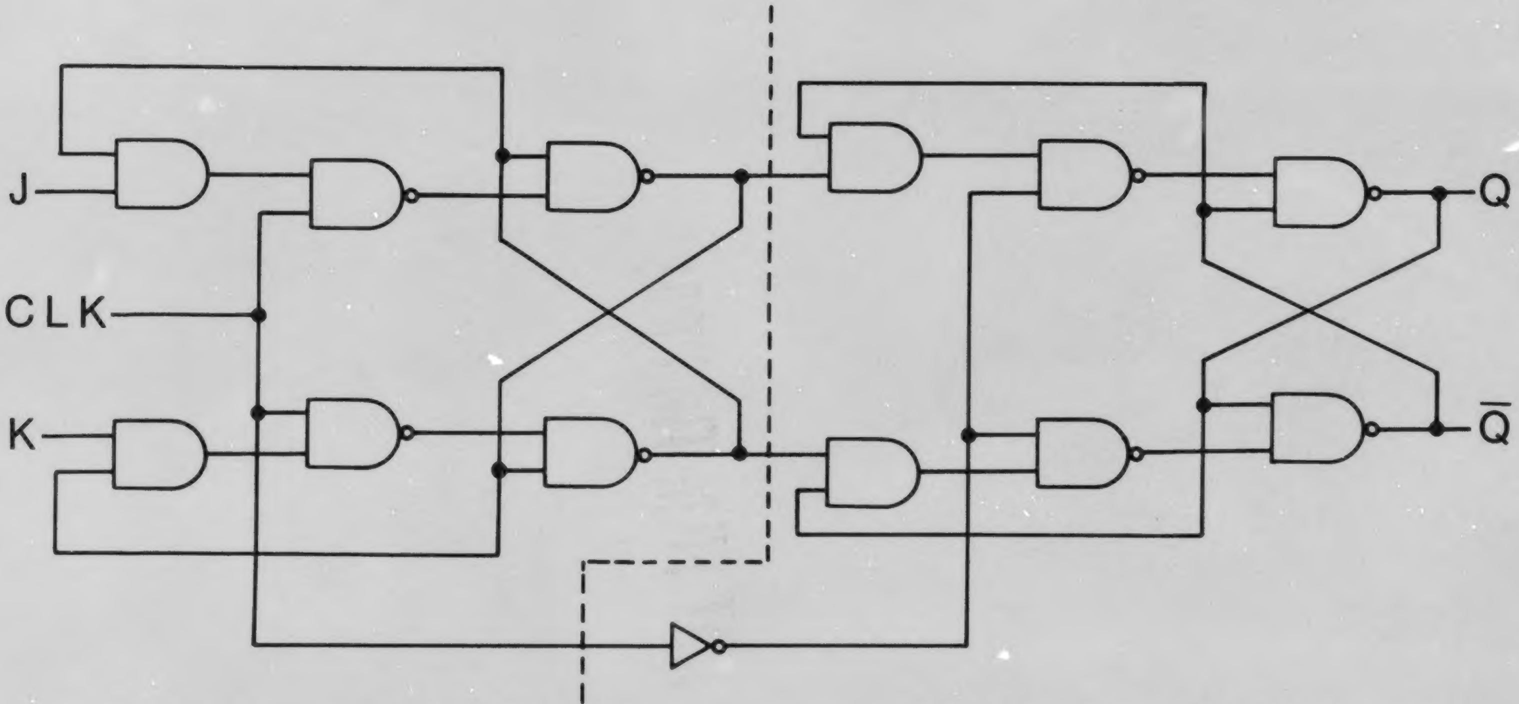

J
CLK
K
Q
$\overline{Q}$



Disable Area
J = 0 K = 0

Toggle Area
J = 1 K = 1

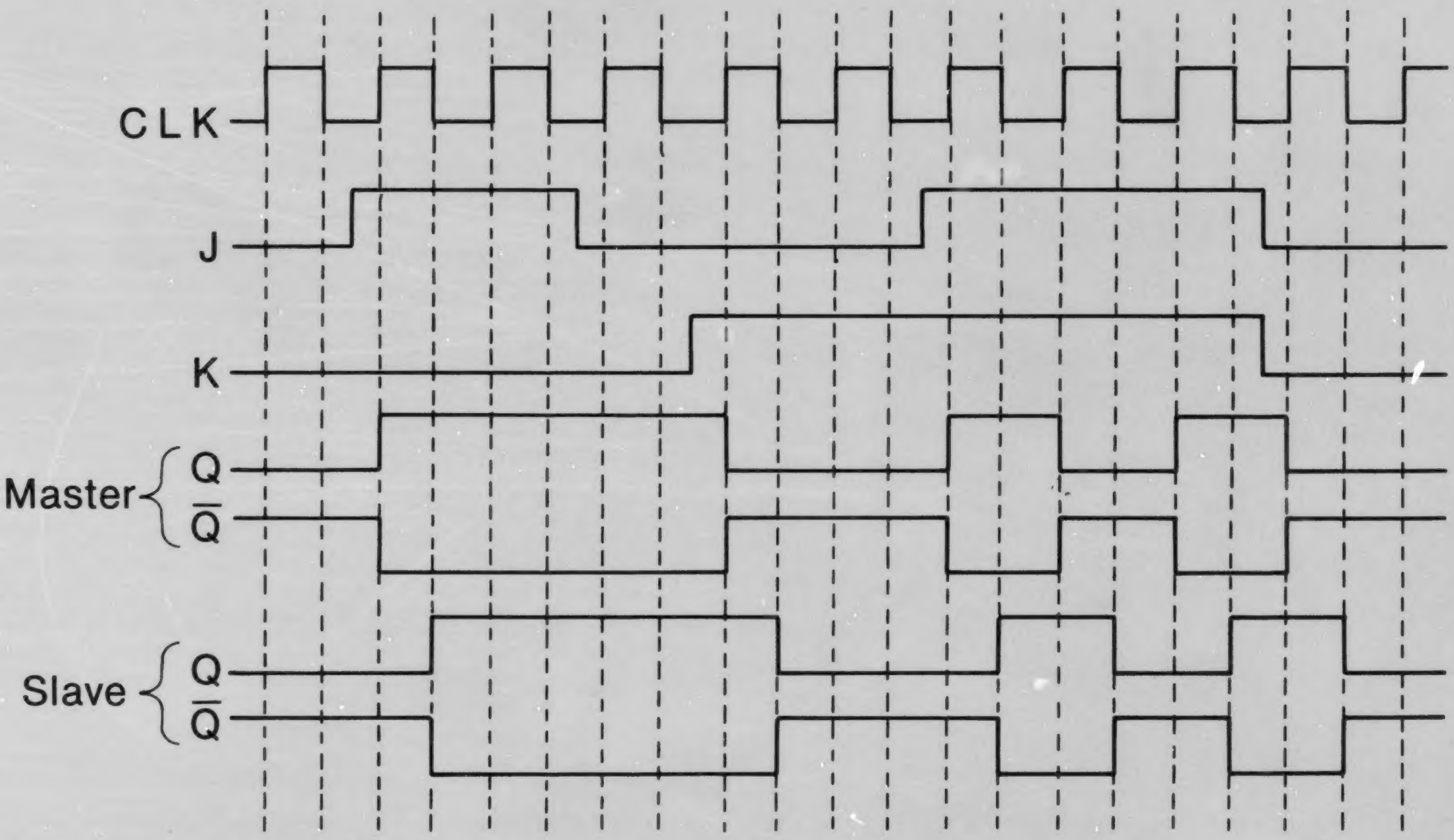
Master/Slave Flip-Flop


J
CLK
K
Q
$\overline{Q}$

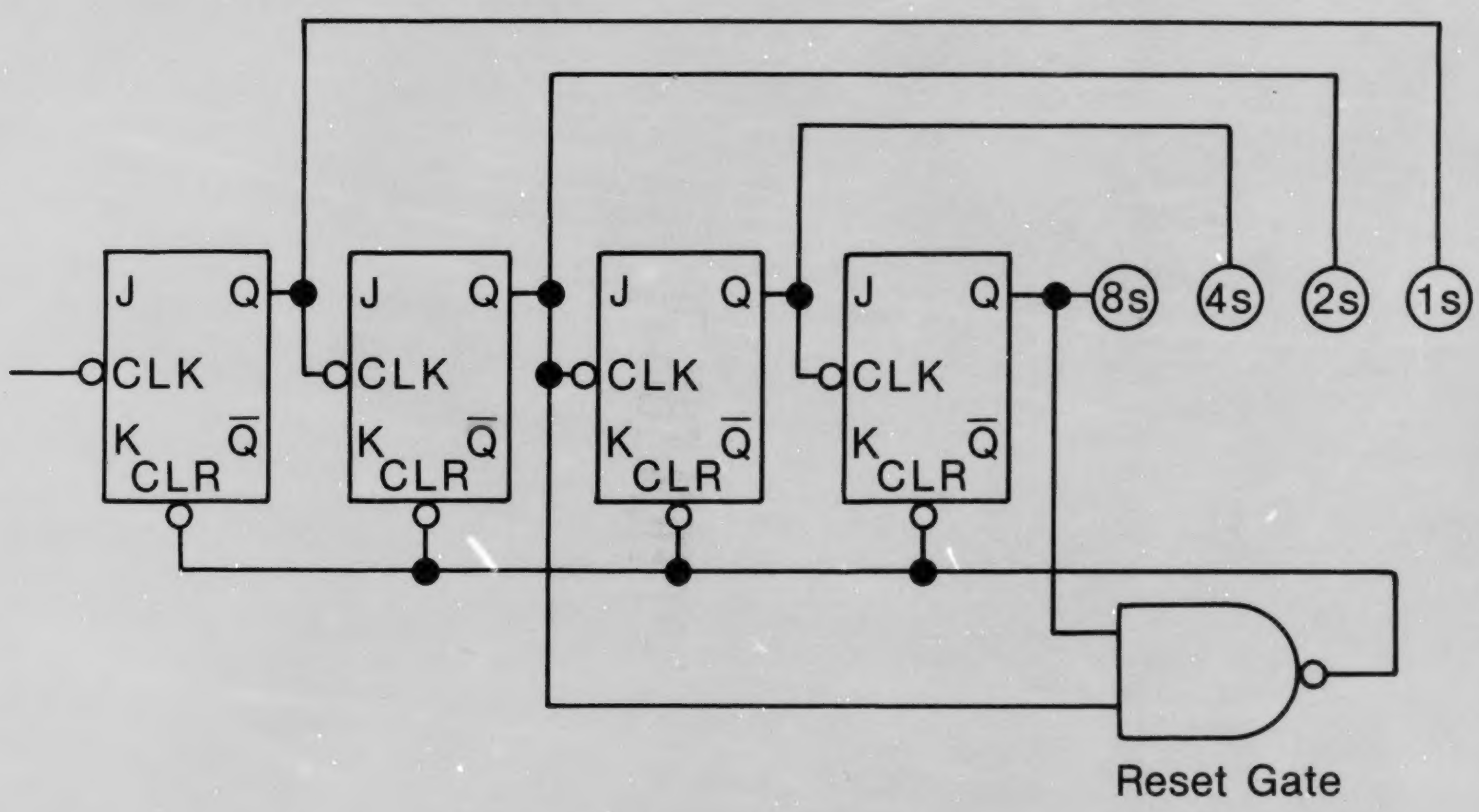
Master or Positive
Edge Flip-Flop

Slave or Negative
Edge Flip-Flop

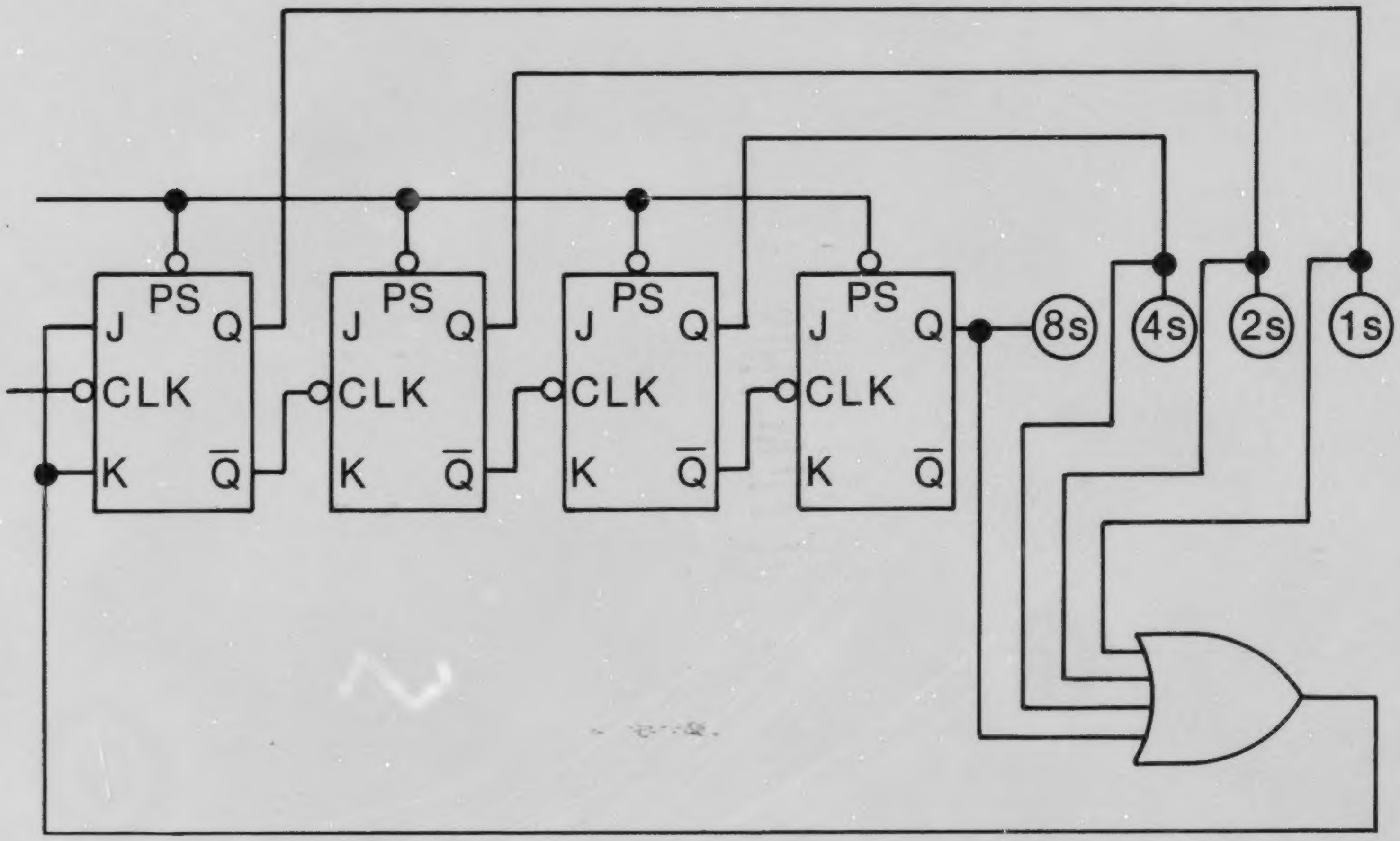
Master/Slave Flip-Flop Waveform


CLK
J
K
Master
Q
$\overline{Q}$
Slave
Q
$\overline{Q}$

Ripple Counter
(Asynchronous, Up, Binary Counter)


J
Q
CLK
K
Q̄
CLR
8s
4s
2s
1s
Reset Gate

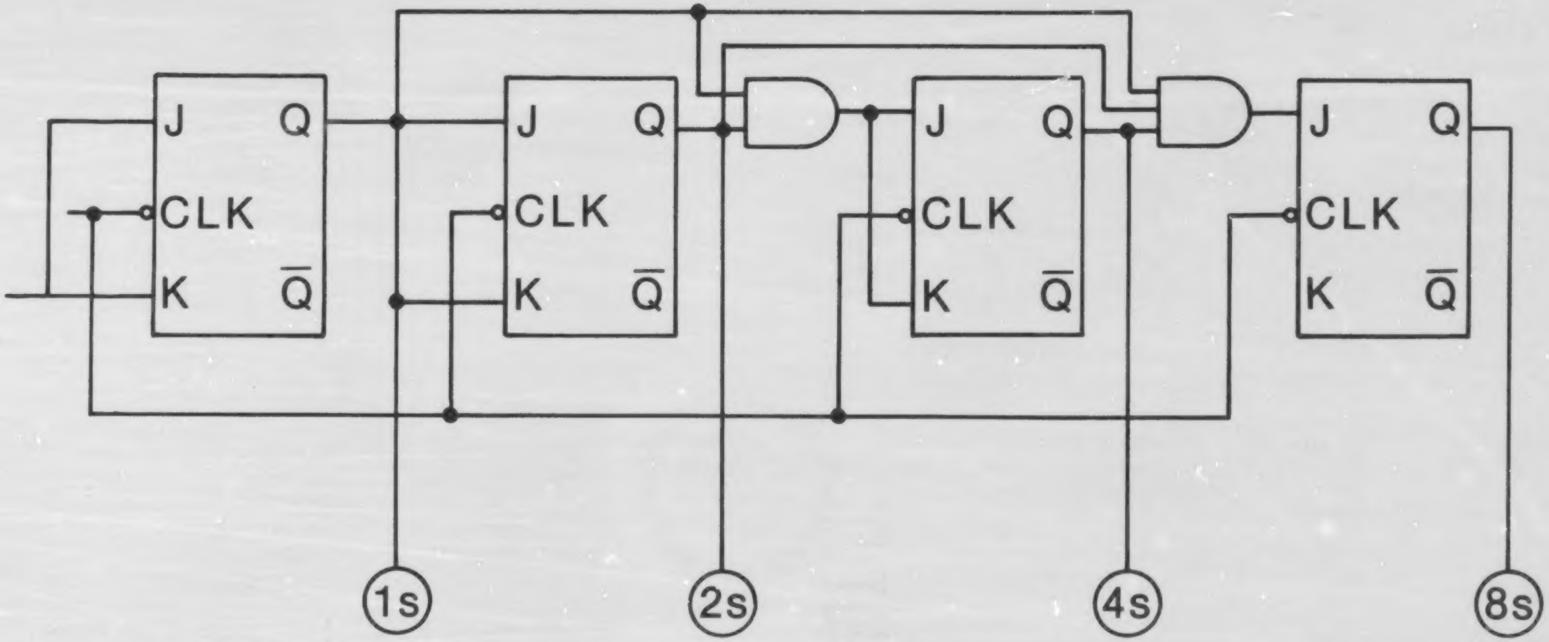
Down Counter
(Asynchronous, Down, Binary Counter)


PS
J
Q
CLK
K
Q̄
8s
4s
2s
1s

TM #7

AIE - 141-B

Synchronous Counter
(Synchronous, Up, Decade Counter)


J
Q
CLK
K
Q̄
1s
2s
4s
8s

233

234

TM #8

AIE - 143-B

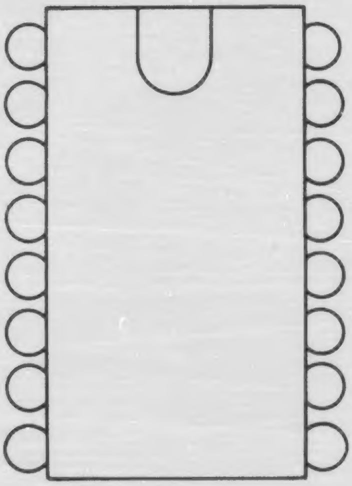
COUNTERS
UNIT IV

ASSIGNMENT SHEET #1 — IDENTIFY INTEGRATED CIRCUIT PIN CONFIGURATIONS

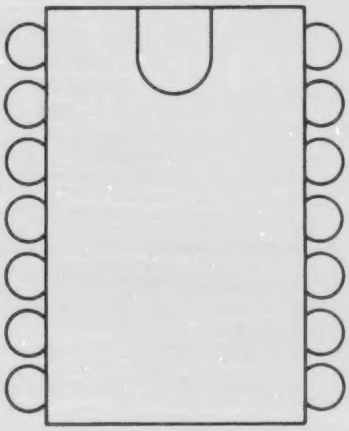
NAME ____ SCORE ________________

As an electronic technician, you will continue to encounter additional integrated circuits; and they will become more complicated. Additional research may be necessary in order to locate some of these integrated circuits.

Use the following diagrams to indicate the function of the IC and identify the various inputs and outputs. You may make additional notes if you desire.

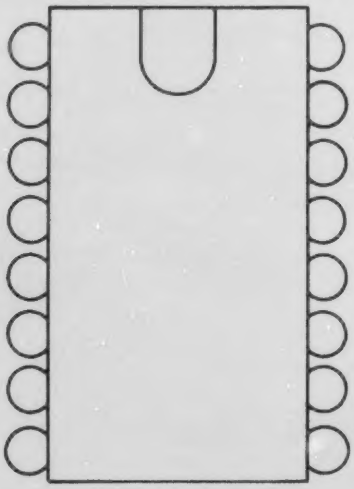


A. 7476 ____________________________



B. 7493 ____________________________

ASSIGNMENT SHEET #1

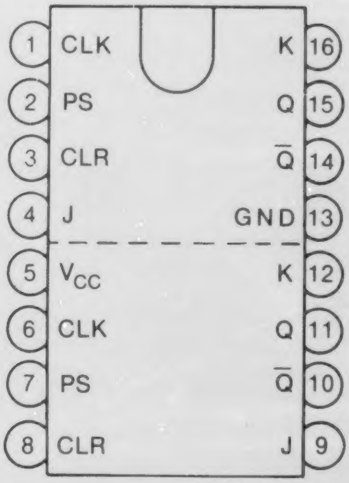


C. 74192 ______________________________

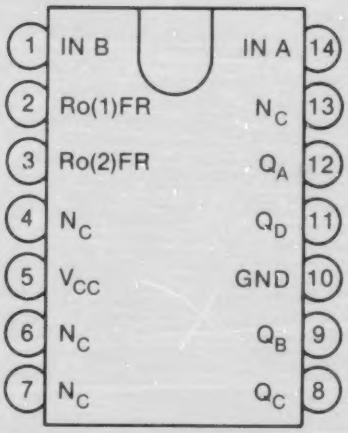
COUNTERS
UNIT IV

ANSWERS TO ASSIGNMENT SHEET

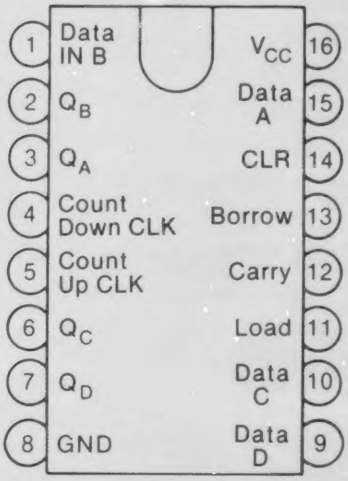
Assignment Sheet #1


1 CLK
2 PS
3 CLR
4 J
5 V_{CC}
6 CLK
7 PS
8 CLR
K 16
Q 15
$\overline{Q}$ 14
GND 13
K 12
Q 11
$\overline{Q}$ 10
J 9

A. 7476 Dual J-K flip-flop


1 IN B
2 Ro(1)FR
3 Ro(2)FR
4 N_C
5 V_{CC}
6 N_C
7 N_C
IN A 14
N_C 13
Q_A 12
Q_D 11
GND 10
Q_B 9
Q_C 8

B. 7493 Four-bit binary counter


1 Data IN B
2 Q_B
3 Q_A
4 Count Down CLK
5 Count Up CLK
6 Q_C
7 Q_D
8 GND
V_{CC} 16
Data A 15
CLR 14
Borrow 13
Carry 12
Load 11
Data C 10
Data D 9

C. 74192 BCD up/down counter

COUNTERS
UNIT IV

JOB SHEET #1 — CONSTRUCT AND ANALYZE AN R-S FLIP-FLOP

I. Equipment and materials

A. Power supply, 5 VDC regulated

B. Two LEDs

C. Resistor, 150 ohm

D. Breadboard

E. Two SPST switches

F. SPST switch, debounced

(NOTE: A digital trainer may be used if it is equipped with the above components.)

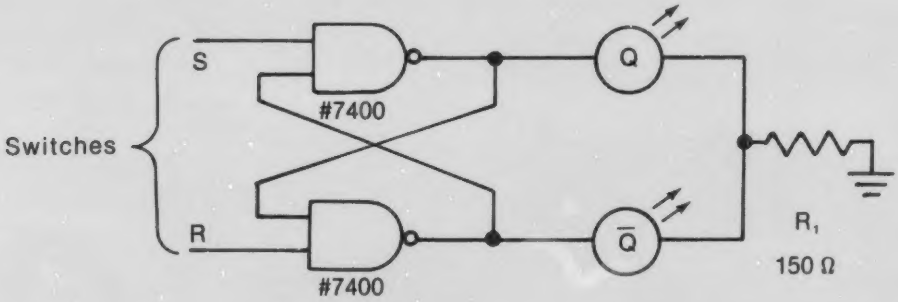
G. Circuit wiring

H. Quad two-input NAND gate, #7400

II. Procedure

A. Construct the circuit shown in Figure 1

FIGURE 1



B. Turn on power

JOB SHEET #1

C. Position the R-S input switches in the positions shown in the top line of Table 1

TABLE 1

Input		Output		
R	S	Q	$\overline{Q}$	Effect on Q
0	0			
1	0			
0	1			
1	1			

D. Record the Q and $\overline{Q}$ outputs in the appropriate spaces in Table 1

E. Record the condition of Q after the data inputs have been applied (prohibit, set, reset, or idle)

F. Continue positioning switches and recording outputs for all inputs of Table 1

G. Turn off power

(NOTE: Discuss your results with the instructor.)

H. Put equipment and materials away

COUNTERS
UNIT IV

JOB SHEET #2 — CONSTRUCT AND ANALYZE A J-K FLIP-FLOP CIRCUIT

I. Equipment and materials

   A. Power supply, 5 VDC regulated

   B. Four LEDs

   C. Resistor, 150 ohm

   D. Breadboard

   E. Two SPST switches

   F. SPST switch, debounced

   (NOTE: A digital trainer may be used if it is equipped with the above components.)

   G. Circuit wiring

   H. Quad two-input NAND gate, #7400

   I. Quad two-input AND gate, #7408

   J. Dual J-K flip-flop, #7476

   K. Hex inverter, #7404

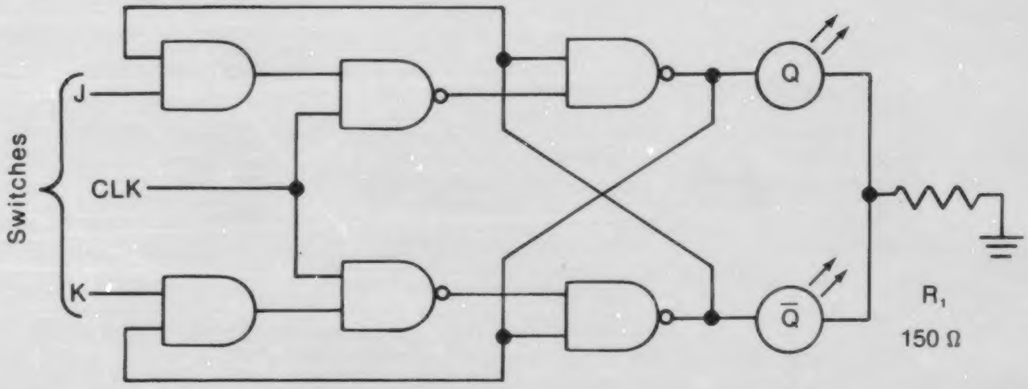
   L. Dual-trace or multichannel oscilloscope

JOB SHEET #2

II. Procedure

A. Construct the circuit shown in Figure 2

FIGURE 2



B. Turn on power

C. Position the J, K, and clock inputs to the positions shown in the top row of Table 2

TABLE 2

Inputs			Outputs				
			Before Clock		After Clock		Condition of Q
CLK	J	K	Q	$\overline{Q}$	Q	$\overline{Q}$	
⎍	0	0					
⎍	1	0					
⎍	0	1					
⎍	1	1					
⎍	1	1					
⎍	1	1					

D. Record the Q and $\overline{Q}$ outputs before and after the clock pulse is applied to the circuit

JOB SHEET #2

E. Record the condition of Q after the data inputs and clock pulse have been applied (disable, set, reset, or toggle)

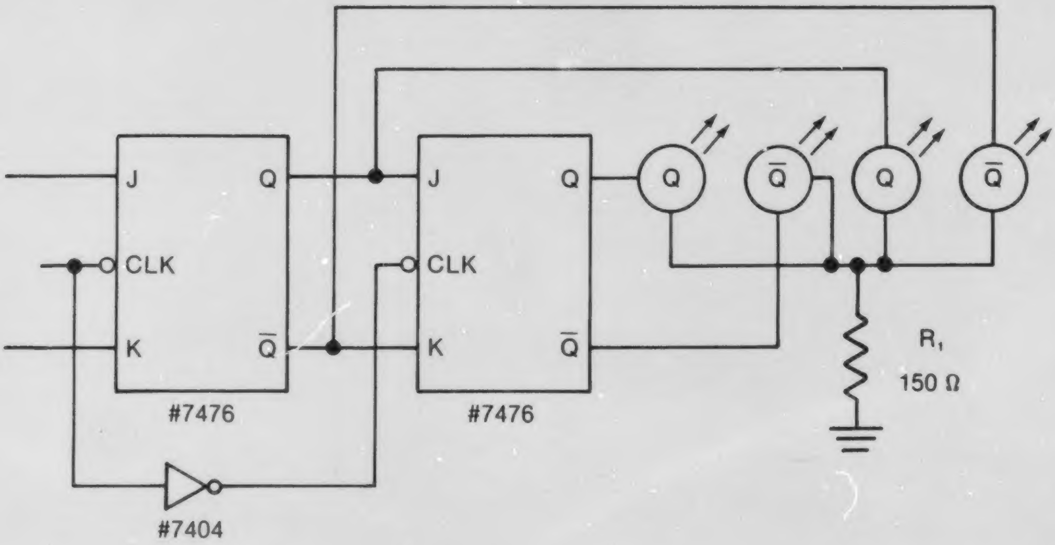
F. Continue steps C, D, and E for all inputs of Table 2

G. Compare your results with the waveforms on Transparency #3

H. Turn off power

I. Construct the circuit as shown in Figure 3

FIGURE 3


J
Q
CLK
K
$\overline{Q}$
#7476
J
Q
CLK
K
$\overline{Q}$
#7476
#7404
Q
$\overline{Q}$
Q
$\overline{Q}$
R₁
150 Ω

J. Turn on power

K. Position the data input switches and the clock pulse as shown in the top line of Table 3

JOB SHEET #2

TABLE 3

Inputs			Outputs							
			Master				Slave			
CLK	J	K	Before CLK		After CLK		Before CLK		After CLK	
			Q	$\overline{Q}$	Q	$\overline{Q}$	Q	$\overline{Q}$	Q	$\overline{Q}$
⎍	0	0								
⎍	1	0								
⎍	0	1								
⎍	1	1								
⎍	1	1								
⎍	1	1								

L. Record Q and $\overline{Q}$ outputs before and after the clock pulse is applied to the circuit

M. Continue steps K and L for each input in Table 3

N. Turn off power

O. Connect the clock input to a free-running clock pulse

P. Turn on power

Q. Connect dual-trace or multichannel oscilloscope to various points on the circuit

R. Compare waveforms as shown on Transparency #5 with the results of the truth table above

S. Analyze the circuit by answering the following questions

1. What type circuit is this?

   ____

2. How do the two stages of the above circuit differ since both are J-K flip-flops?

   ____

   ____

JOB SHEET #2

T. Turn off power

(NOTE: Discuss your results with the instructor before disassembling the circuit.)

U. Put equipment and materials away

COUNTERS
UNIT IV

JOB SHEET #3 — CONSTRUCT AND ANALYZE A RIPPLE COUNTER

I. Equipment and materials

A. Power supply, 5 VDC regulated

B. Four LEDs

C. Two resistors, 150 ohm

D. Breadboard

E. Two SPST switches

F. SPST switch, debounced

(NOTE: A digital trainer may be used if it is equipped with the above components.)

G. Circuit wiring

H. Two dual J-K flip-flops, #7476

I. Quad two-input NAND gate, #7400

J. Four-bit binary counter, #7493

K. BCD to seven segment decoder, #7447

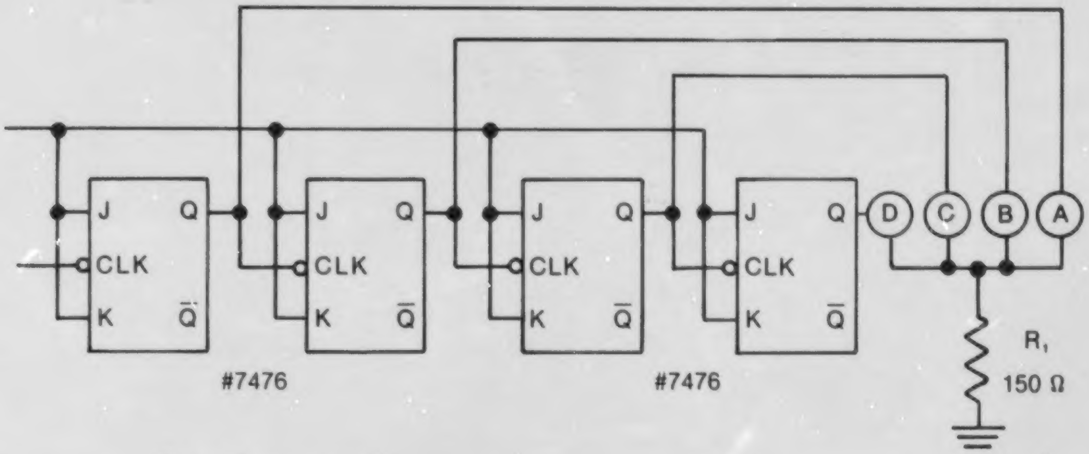
L. Seven-segment display

JOB SHEET #3

II. Procedure

A. Construct the circuit shown in Figure 4

FIGURE 4


J
Q
CLK
K
Q̄
J
Q
CLK
K
Q̄
J
Q
CLK
K
Q̄
J
Q
CLK
K
Q̄
#7476
#7476
D
C
B
A
R,
150 Ω

B. Turn on power

C. Apply a high to the J and K inputs

D. Apply clock pulses as indicated in Table 4

(NOTE: Each time a clock pulse is applied to the ripple counter, the binary readout should increase by one.)

JOB SHEET #3

E. Record the binary readouts in the spaces provided

TABLE 4

Input	Output				
Clock Pulse #	A	B	C	D	Decimal #
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					

F. What does the bubble on each clock input represent?

____

G. Turn off power

H. Replace the J-K flip-flops, #7476 ICs, with the #7493, four-bit counter

JOB SHEET #3

I. Turn on power

J. Pulse the clock input through 16 pulses

K. Compare the LED indications with those received in step E

L. Did the LED outputs in step J match those in step E?

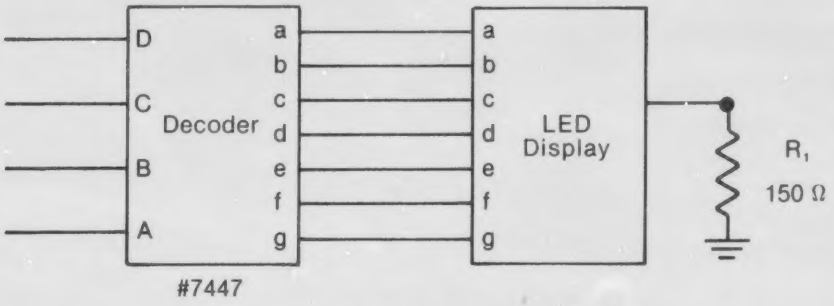
____

(NOTE: As can be seen from the above results, the ripple circuit constructed from AND and NAND gates, the #7476 J-K flip-flop ICs or the #7493 four-bit binary counter will function comparatively. Each method becomes simpler in construction with less possibility of error.)

M. Turn off power

N. Add the circuit shown below to either or both of the above circuits, leaving the LEDs connected (Figure 5)

FIGURE 5



O. Turn on power

P. Apply clock pulses as indicated in Table 4

Q. Record the decimal numbers in the spaces provided in Table 4

R. Answer the following questions

1. Do the decimal numbers match the binary numbers?

____

JOB SHEET #3

2. The ripple counter may also be called a ______________________,

______________________________, or _________________________.

(NOTE: The mod-16 or ripple counter can be made into a mod-10 counter by adding a NAND gate from the flip-flop two output and the flip-flop four output. The NAND output is then applied as a zero pulse to the clear inputs of each flip-flop.)

S. Turn off power

(NOTE: Discuss your results with the instructor before disassembling circuit.)

T. Put equipment and materials away

COUNTERS
UNIT IV

JOB SHEET #4 — CONSTRUCT AND ANALYZE AN UP/DOWN COUNTER

I. Equipment and materials

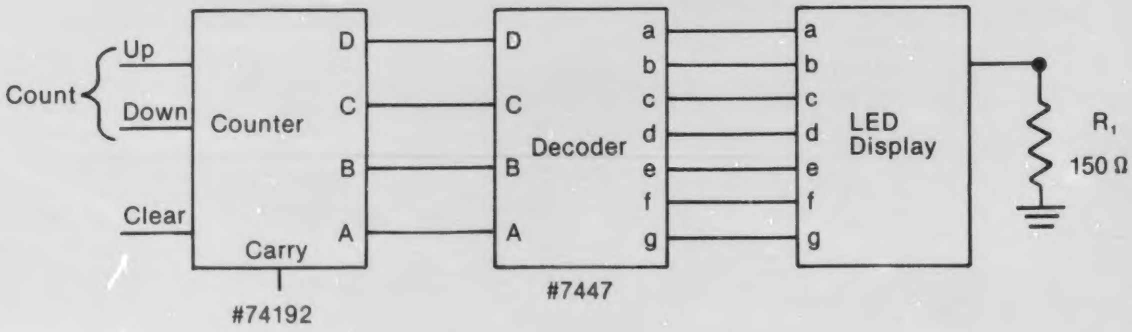
- A. Power supply, 5 VDC regulated
- B. Four LEDs
- C. Two resistors, 150 ohm
- D. Breadboard
- E. SPST switch
- F. SPST switch, debounced

  (NOTE: A digital trainer may be used if it is equipped with the above components.)
- G. Circuit wiring
- H. Two BCD up/down counters, #74192
- I. Two BCD to seven segment decoders, #7447
- J. Two seven-segment displays

II. Procedure

- A. Construct the circuit shown in Figure 6

FIGURE 6


Count
Up
Down
Clear
Counter
D
C
B
A
Carry
#74192
Decoder
a
b
c
d
e
f
g
#7447
LED Display
R_1
150 Ω

JOB SHEET #4

P. Is the circuit now an up or down counter?

____

Q. Turn off power

R. Reconnect the clock input pulse to the up input

S. Leaving the above circuit connected, construct another circuit identical to the one above

T. Connect the clear input to both counter integrated circuits

U. Connect the carry output from the first circuit to the count up input of the second circuit

V. Turn on power

W. Apply a high or one to clear both LED displays and return to a low or zero input

(NOTE: Both LED displays should now be zero.)

X. Indicate the first LED display as the one's display and the second circuit display as the ten's display

Y. Pulse the clock input through at least twenty pulses

Z. Record the results

____

____

AA. Turn off power

(NOTE: Additional digits may be added by adding additional circuits for each digit. Discuss your results with the instructor before disassembling the circuit.)

BB. Put equipment and materials away

COUNTERS
UNIT IV

TEST

NAME ____ SCORE ________________

1. Match terms associated with counters to their correct definitions. Write the correct numbers in the blanks.

______a. Controlled by equally spaced clock pulses

______b. Counter-triggered by high only or low only input

______c. To place a counter into a state that permits an action to occur on the next clock pulse

______d. Counter in which all the flip-flops trigger sequentially; often called a *sequential counter*

______e. To place a storage circuit into one of two states

______f. Not controlled by clock pulses

______g. Indication of how many states there are in a binary counter circuit

______h. Circuit that can remain in one of two positions, either low or high, and must be activated by a trigger or clock pulse; also called a *bistable multivibrator*

______i. Counter that has ten stable states

______j. Counter triggered by any change in input

______k. Electronic pulse that starts an action in a circuit

______l. Flip-flop circuit that changes states on each clock pulse

______m. To return a storage circuit to an initial state

______n. Pulse used to gate information in a digital flip-flop circuit, often called a *trigger pulse*

______o. Counter circuit that counts through sixteen different states, or a count from 0 through 15

1. Modulo
2. Decade counter
3. Allow
4. Synchronous
5. Asynchronous
6. Set
7. Ripple counter
8. Edge-triggered counter
9. Flip-flop circuit
10. Level-triggered counter
11. Clock pulse
12. Four-bit binary counter
13. Toggle
14. Trigger
15. Reset

TEST

2. Distinguish among characteristics of common flip-flop circuits. Write the circuit abbreviations "R-S", "D", "J-K", or "M/S" in the blanks before their correct characteristics. A blank may have more than one answer.

_____a. Will remain in the previous state if R and S are high

_____b. Generates the same output after a clock pulse as the input

_____c. Requires two data inputs, J and K, plus a clock pulse

_____d. Will change states on each clock pulse once the clock pulse goes high and will continue to change states on each pulse if the clock pulse becomes low

_____e. Will change states at the next clock pulse if either data input, but not both inputs, is high

_____f. Master flip-flop will change states on each positive clock pulse if both data inputs are high

_____g. Slave flip-flop will copy the action of the master flip-flop after a delay of one clock pulse

_____h. Uses a K input that is the reset input and will set the flip-flop on the next clock pulse *if* the input is high *and* the flip-flop is in the set state

_____i. Requires two data inputs, set (S) and reset (R)

_____j. Will not function if R and S are in the zero state at the same time

_____k. Will change states on each clock pulse if both data inputs are high; this is called *toggling*

_____l. Requires only one external data input plus a clock pulse

_____m. Is disabled and the clock pulse will not change the circuit state if both data inputs are low

_____n. Slave flip-flop will change states on each negative clock pulse if both data inputs are high

_____o. Uses a J input that is the set input and will set/allow the flip-flop on the next clock pulse *if* the input is high *and* the flip-flop is in the reset state

TEST

3. List ways of classifying counters.

   a. ______________________________

   b. ______________________________

   c. ______________________________

(NOTE: Test questions 4 and 5 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

4. Identify integrated circuit pin configurations.

5. Demonstrate the ability to

   a. Construct and analyze an R-S flip-flop.

   b. Construct and analyze a J-K flip-flop circuit.

   c. Construct and analyze a ripple counter.

   d. Construct and analyze an up/down counter.

COUNTERS
UNIT IV

ANSWERS TO TEST

1. a. 4
   b. 10
   c. 3
   d. 7
   e. 6
   f. 5
   g. 1
   h. 9
   i. 2
   j. 8
   k. 14
   l. 13
   m. 15
   n. 11
   o. 12

2. a. R-S
   b. D
   c. J-K, M/S
   d. M/S
   e. J-K
   f. M/S
   g. M/S
   h. J-K
   i. R-S
   j. R-S
   k. J-K
   l. D
   m. J-K
   n. M/S
   o. J-K

3. a. Up or down
   b. Decade or binary
   c. Synchronous or asynchronous

4. Evaluated to the satisfaction of the instructor

5. Performance skills evaluated to the satisfaction of the instructor

MEMORY CIRCUITS
UNIT V

UNIT OBJECTIVE

After completing this unit, the student should be able to construct and analyze various registers and memory circuits. The student will show this knowledge by completing the assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with memory circuits to their correct definitions.
2. Select from a list characteristics of shift registers.
3. Distinguish among characteristics of basic types of shift registers.
4. Distinguish between types of computer data storage.
5. List types of computer memories.
6. Distinguish among characteristics of memory circuits.
7. Identify integrated circuit pin configurations.
8. Demonstrate the ability to
    a. Construct and analyze a serial shift register.
    b. Construct and analyze a parallel shift register.
    c. Construct and analyze a universal shift register.
    d. Construct and analyze a random-access memory circuit.

MEMORY CIRCUITS
UNIT V

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Provide students with objective sheet.

   C. Discuss unit and specific objectives.

   D. Provide students with information, assignment, and job sheets.

   E. Discuss information sheet.

   F. Demonstrate and discuss procedures outlined in assignment and job sheets.

   G. Demonstrate various memories by showing students a temporary memory and a constant memory in various calculators. (The TI-30 uses a temporary memory whereas the TI-35 uses a constant memory.)

   H. Discuss with the students various types of computer memories.

   I. Tour various industries that use computers, and discuss their use of memory devices.

   J. Give test.

II. Instructional materials

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM #1 — Serial Shift Register

      2. TM #2 — Parallel Shift Register

      3. TM #3 — Universal Shift Register

   D. Assignment Sheet #1 — Identify Integrated Circuit Pin Configurations

   E. Answers to assignment sheet

SUGGESTED ACTIVITIES

F. Job sheets

1. Job Sheet #1 — Construct and Analyze a Serial Shift Register
2. Job Sheet #2 — Construct and Analyze a Parallel Shift Register
3. Job Sheet #3 — Construct and Analyze a Universal Shift Register
4. Job Sheet #4 — Construct and Analyze a Random-Access Memory Circuit

G. Test

H. Answers to test

III. Unit references

A. Barber, Alfred W. *Practical Guide to Digital Integrated Circuits.* West Nyack, New York: Parker Publishing Co., Inc., 1976.

B. Malvino, Albert Paul. *Digital Computer Electronics.* New York: McGraw Hill, 1977.

C. McWhorter, Gene. *Understanding Digital Electronics.* Fort Worth, Texas: Radio Shack, 1978.

D. Tokheim, Roger L. *Digital Electronics.* New York: McGraw Hill, 1979.

MEMORY CIRCUITS
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Data — Information such as numbers, letters, symbols, or other information to be processed by a computer

B. Bit — Abbreviation for *bi*nary digi*t*; information in the form of a one or a zero stored in one computer cell

C. Memory — Area of an electronic device where information is stored

D. Volatile memory — Memory that loses all its data when the power is removed

E. Nonvolatile memory — Memory that retains its data even if power is removed

F. Register — Temporary storage unit for digital information

(NOTE: Registers may be located in subsystems outside the memory and usually contain only one bit of information, such as a shift command response. Information can be both stored and operated on in the register.)

G. Shift register — Register in which the stored data can be moved to the right or left

(NOTE: Some registers allow movement to the left, others to the right, and others to the left or right.)

H. Address — Pattern of characters that identifies a particular storage location

I. Word — One bit or group of bits stored at one address in a memory

J. Write — To copy information, transfer information, or record information in a certain location in a memory

K. Read — To extract information from a memory

L. Serial loading — Feeding one bit of data at a time into register or memory

M. Parallel loading — Feeding several bits of data into register or memory at the same time

INFORMATION SHEET

N. Peripherals — Devices located outside the central processing unit

EXAMPLES: Printer, modem

O. Bubble — Discrete area or domain in the field of a magnetic material

(NOTE: Bubbles can be created and moved within the magnetic field. This allows the use of magnetic field for memory storage.)

II. Characteristics of shift registers

A. Connect flip-flops in series

B. Use memory characteristics of flip-flops

C. Hold information for temporary storage

D. Are available as integrated circuits (ICs)

(NOTE: Two popular IC shift registers are the 7496, which is a five flip-flop circuit, and the 74194, which is a four flip-flop circuit. The 74194 will be referred to and used throughout this unit.)

E. Generally have capacity of 4, 5, or 8 bits

III. Characteristics of basic types of shift registers (Transparencies #1-#3)

A. Serial shift register — Can accept only one bit of data at a time

B. Parallel shift register — Can accept several bits of information at one time and enter them into the register by one clock pulse

C. Universal shift register

1. Can accept data serially or in parallel

2. Can shift either left or right

IV. Types of computer data storage

A. Internal memory — Semiconductor data storage

B. External data storage

1. Punched cards

2. Punched tape

3. Magnetic tape

4. Disc and drum

INFORMATION SHEET

V. Types of computer memories

   A. Random-access memory (RAM)

   B. Read-only memory (ROM)

   C. Programmable read-only memory (PROM)

   D. Erasable programmable read-only memory (EPROM)

   E. Electrically erasable programmable read-only memory (EEPROM)

   F. Bubble memory

VI. Memory characteristics

   A. Random-access memory (RAM) — Loses all data when power to memory is removed

   (NOTE: RAM is used in digital and computer circuits where only a temporary storage is required.)

   B. Read-only memory (ROM)

      1. Has permanent information programmed by manufacturer

      2. Is unalterable by user

      3. Allows more data storage per user than RAM

   C. Programmable read-only memory (PROM)

      1. Can be programmed permanently if procedure obtained from manufacturer is followed

      2. Blows fuses selectively within the IC for the one-time write process

      3. Is permanent and functions like a ROM once memory is programmed

INFORMATION SHEET

D. Erasable programmable read-only memory (EPROM)

   1. Can be programmed permanently if procedure obtained from manufacturer is followed
   2. Can be erased and reprogrammed if procedure obtained from manufacturer is followed
   3. Retains data even if power is removed

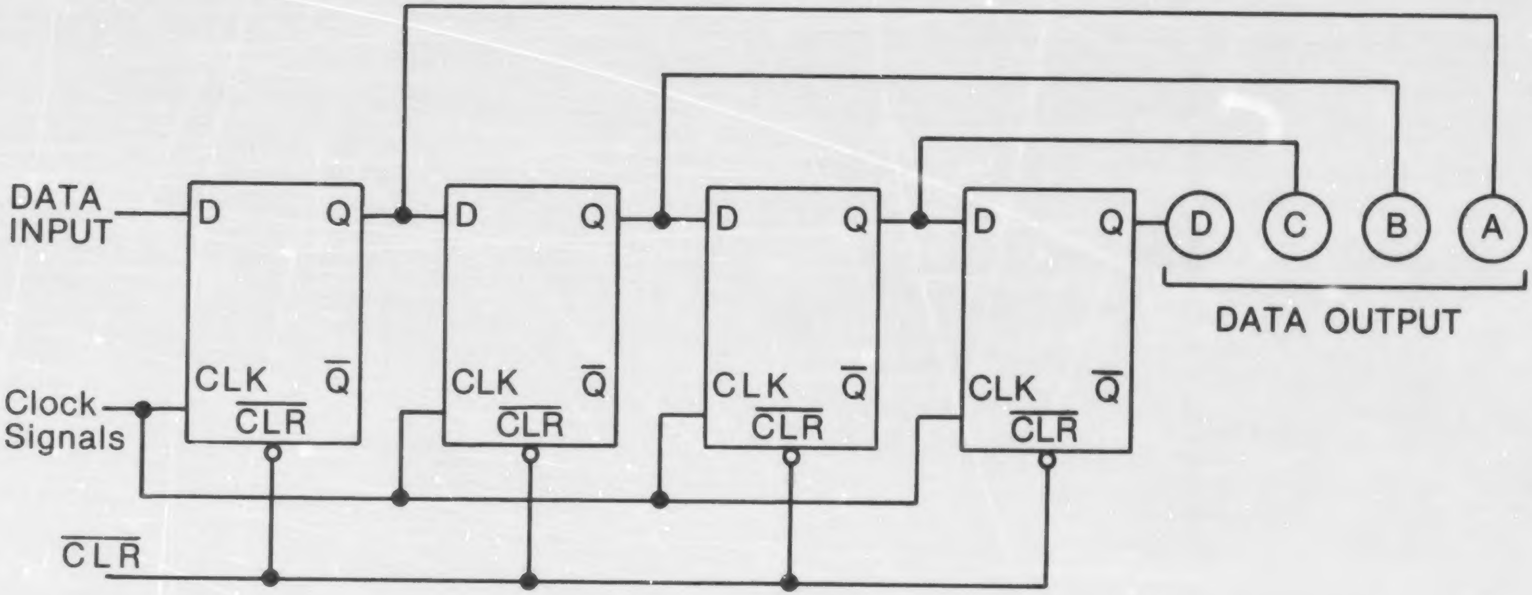
E. Electrically erasable programmable read-only memory (EEPROM)

   1. Can be programmed permanently if procedure obtained from manufacturer is followed
   2. Can be erased and reprogrammed if procedure obtained from manufacturer is followed
   3. Retains data even if power is removed
   4. Can be erased electrically while IC is still in machine

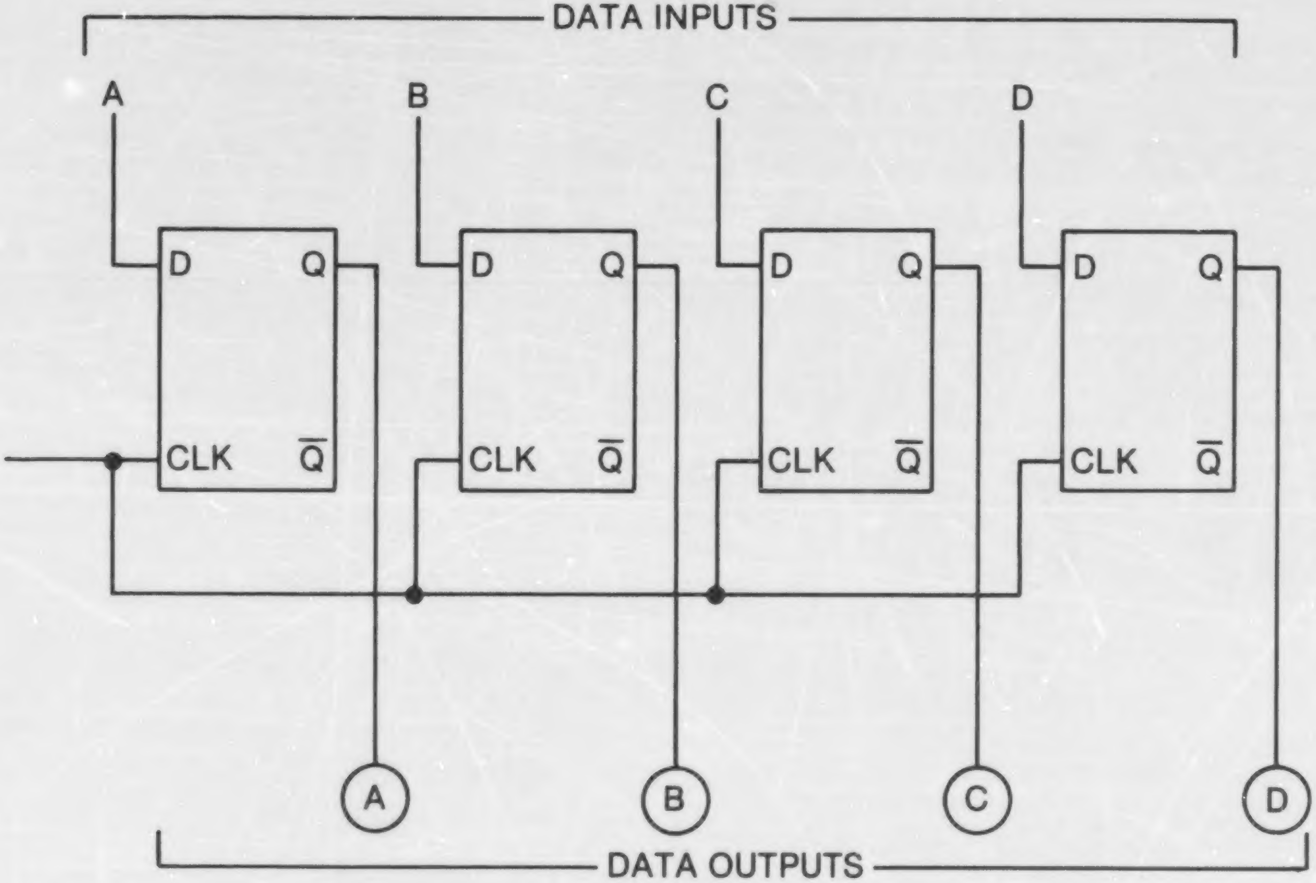
F. Bubble memory

   1. Uses permanent magnets so that memory is nonvolatile
   2. Uses magnetic fields to control formation and movement of bubbles

Serial Shift Register


DATA INPUT
Clock Signals
CLR
D
Q
CLK
Q
CLR
D
C
B
A
DATA OUTPUT

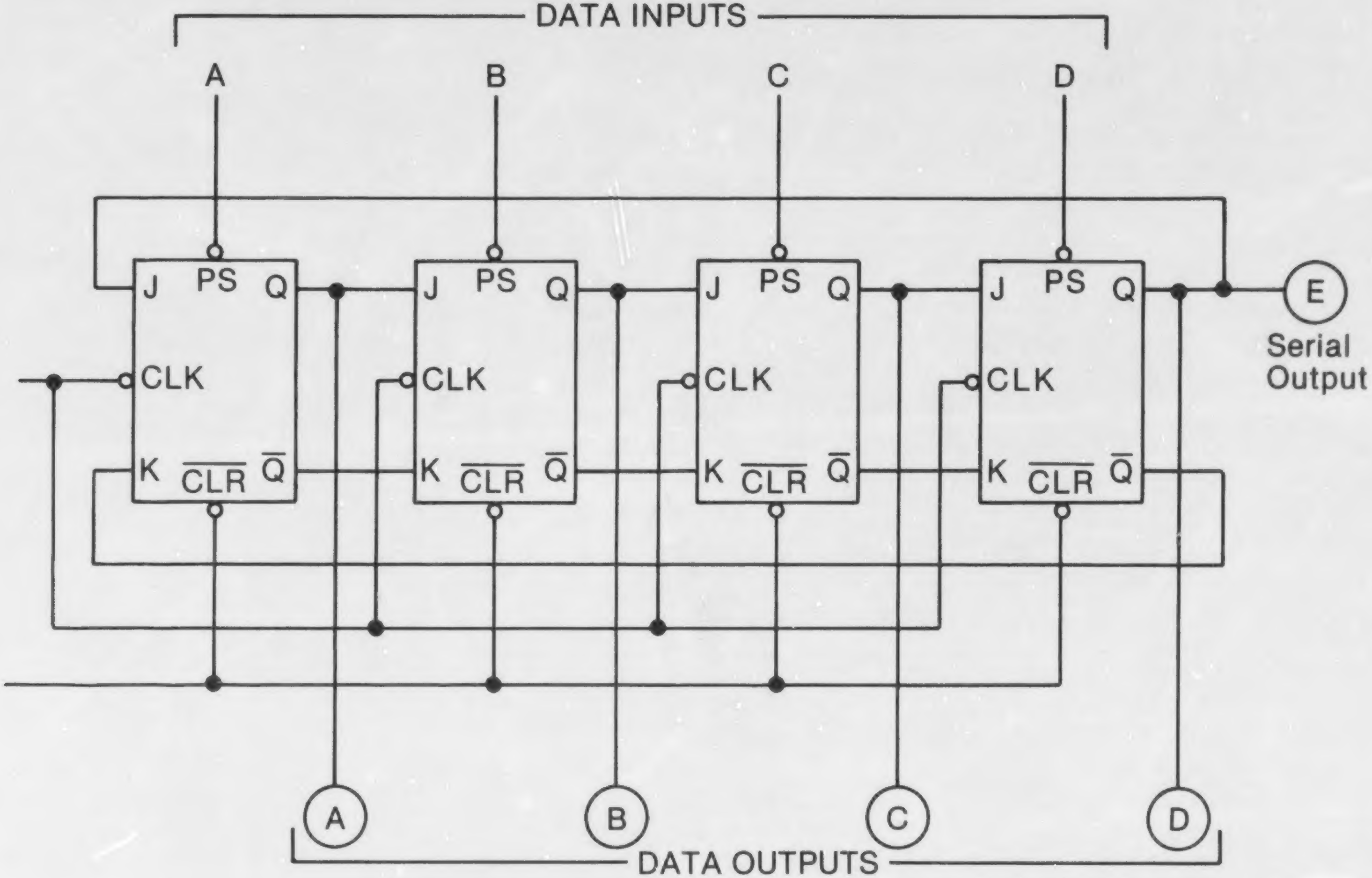
Parallel Shift Register


DATA INPUTS
A
B
C
D
D
Q
CLK
$\overline{Q}$
A
B
C
D
DATA OUTPUTS

TM #2

AIE - 181-B

Universal Shift Register


DATA INPUTS
A
B
C
D
J
PS
Q
CLK
K
CLR
Q̄
E
Serial Output
A
B
C
D
DATA OUTPUTS

TM #3

AIE - 183-B

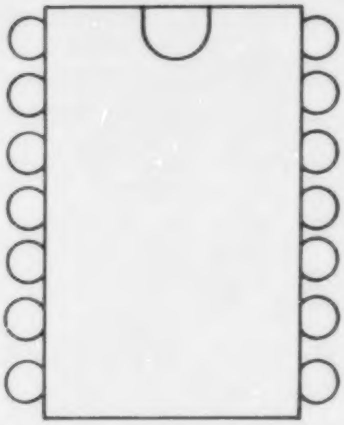
MEMORY CIRCUITS
UNIT V

ASSIGNMENT SHEET #1 — IDENTIFY INTEGRATED CIRCUIT PIN CONFIGURATIONS

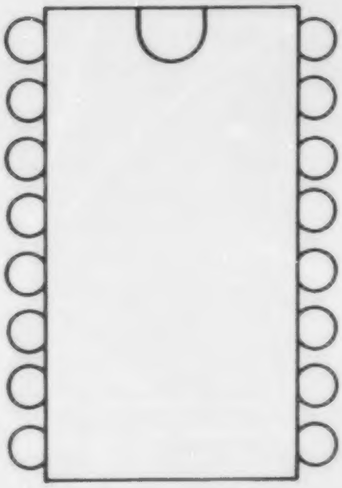
NAME ______________________________ SCORE ______________

Shown below are various integrated circuits that will be used in the following job sheets and that you will encounter as an electronics technician.

Use the following diagrams to indicate the function of the IC and identify the various inputs and outputs.

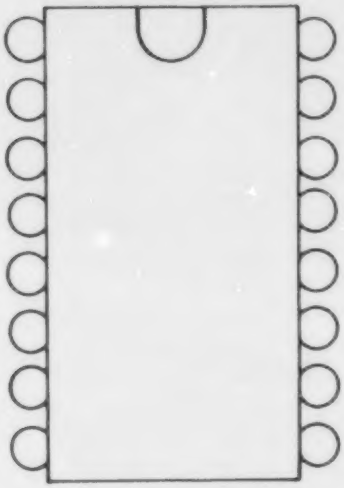


A. 7474 ______________________



B. 7489 ______________________

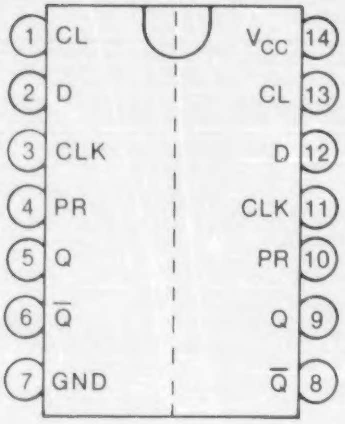
ASSIGNMENT SHEET #1



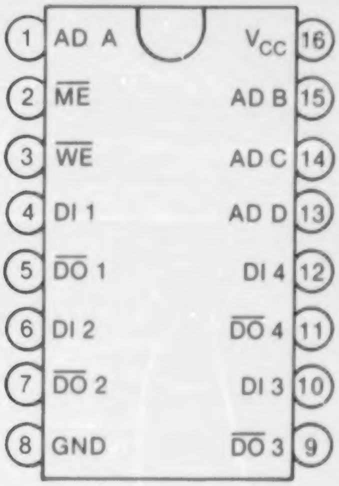
C. 74194 ______________________

MEMORY CIRCUITS
UNIT V

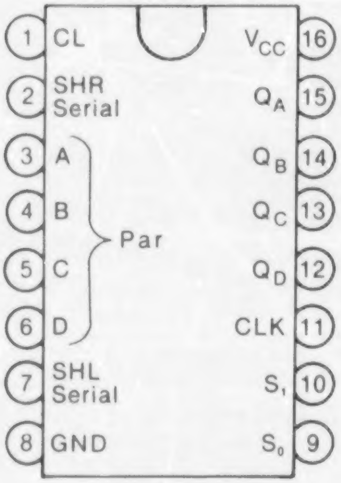
ANSWERS TO ASSIGNMENT SHEET #1


1 CL
2 D
3 CLK
4 PR
5 Q
6 $\overline{Q}$
7 GND
V_{CC} 14
CL 13
D 12
CLK 11
PR 10
Q 9
$\overline{Q}$ 8

A. 7474 Dual D Triggered Flip-Flop


1 AD A
2 $\overline{ME}$
3 $\overline{WE}$
4 DI 1
5 $\overline{DO}$ 1
6 DI 2
7 $\overline{DO}$ 2
8 GND
V_{CC} 16
AD B 15
AD C 14
AD D 13
DI 4 12
$\overline{DO}$ 4 11
DI 3 10
$\overline{DO}$ 3 9

B. 7489 Read/Write Memory


1 CL
2 SHR Serial
3 A
4 B
5 C
6 D
Par
7 SHL Serial
8 GND
V_{CC} 16
Q_A 15
Q_B 14
Q_C 13
Q_D 12
CLK 11
S_1 10
S_0 9

C. 74189 4-Bit Universal Shift Register

MEMORY CIRCUITS
UNIT V

JOB SHEET #1 — CONSTRUCT AND ANALYZE A SERIAL SHIFT REGISTER

I. Equipment and materials

A. Power supply, 5 VDC regulated

B. Four LEDs

C. Four resistors, 150 ohm

D. Breadboard

E. Two SPST switches

F. SPST switch, debounced

(NOTE: A digital trainer may be used if it is equipped with the above components.)

G. Circuit wiring

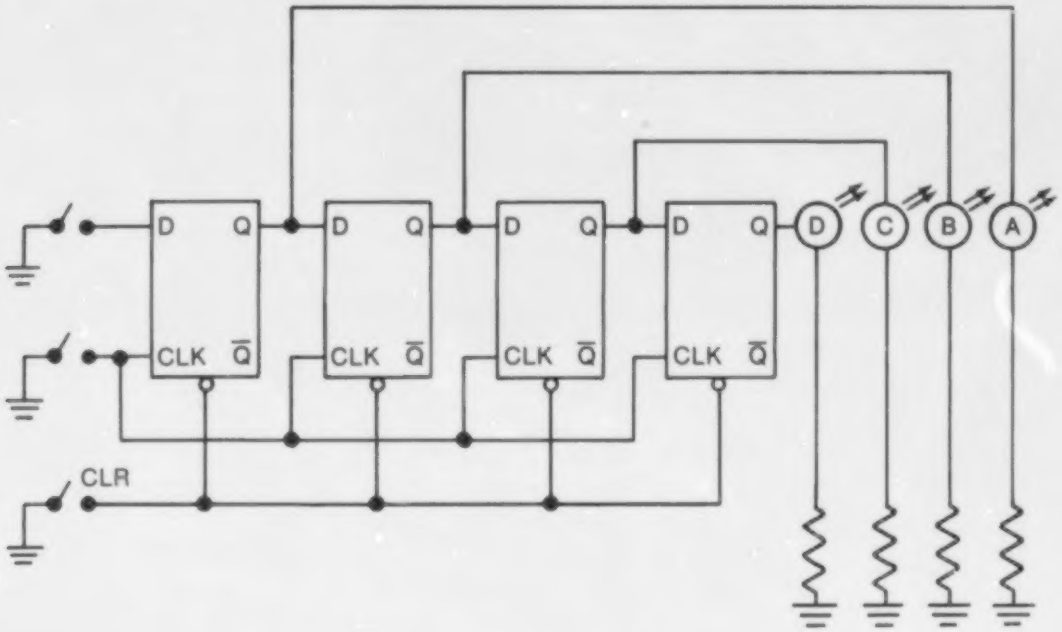
H. Two dual D flip-flops, #7474

JOB SHEET #1

II. Procedure

A. Construct the circuit shown in Figure 1

FIGURE 1


D
Q
CLK
Q̄
D
Q
CLK
Q̄
D
Q
CLK
Q̄
D
Q
CLK
Q̄
CLR
D
C
B
A

(NOTE: Have instructor check circuit.)

B. Turn on power

JOB SHEET #1

C. Position the input circuit switches as indicated in first line of Table 1

TABLE 1

Inputs			Outputs			
CL	D	CLK	A	B	C	D
0	0	1				
1	1	1				
1	1	0				
1	1	1				
1	0	0				
1	0	1				
1	0	0				
1	0	1				
1	1	0				
1	0	1				
1	1	0				
1	0	1				
1	0	0				
1	0	1				
1	0	0				

D. Record outputs A through D in Table 1

E. Continue steps C and D for each line of Table 1

F. Turn off power

G. Analyze the circuit by answering the following questions

1. Is this shift register a left or right register?

   ____

2. How would you clear the circuit without shifting the digits out?

   ____

   ____

JOB SHEET #1

3. Explain why this register is termed a serial shift register

(NOTE: If you have any questions about the circuit, check with the instructor.)

H. Turn on power

I. Practice loading specific data combinations into the register; i.e., 1011, 1001, 1110, 0001, etc.

(NOTE: Discuss your results with the instructor.)

J. Turn off power

K. Put equipment and materials away

MEMORY CIRCUITS
UNIT V

JOB SHEET #2 — CONSTRUCT AND ANALYZE A PARALLEL SHIFT REGISTER

I. Equipment and materials

  A. Power supply, 5 VDC regulated

  B. Eight LEDs

  C. Eight resistors, 150 ohm

  D. Breadboard

  E. Five SPST switches

  F. SPST switch, debounced

  (NOTE: A digital trainer may be used if it is equipped with the above components.)

  G. Circuit wiring

  H. Four dual D flip-flops, #7474

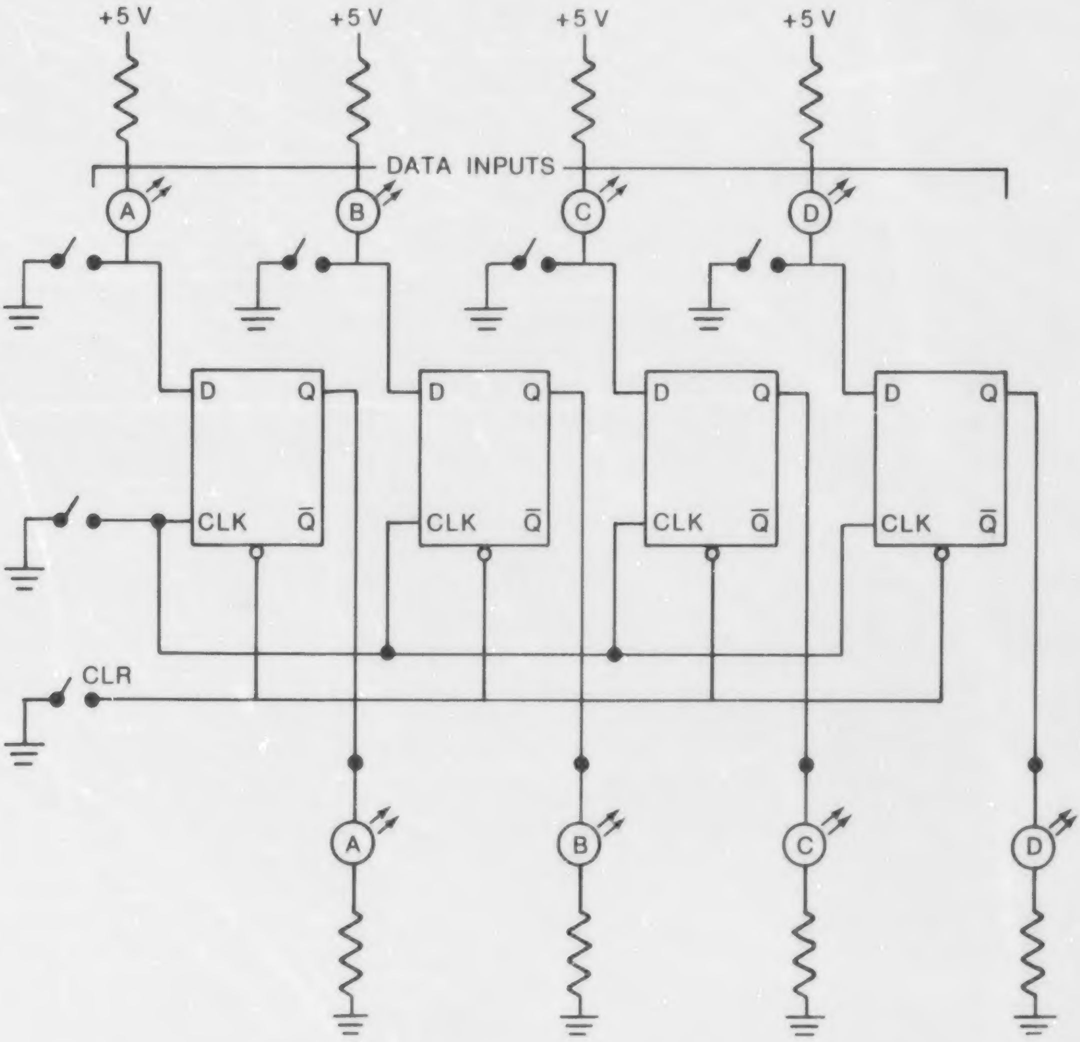
JOB SHEET #2

II. Procedure

A. Construct the circuit shown in Figure 2

FIGURE 2

Parallel Shift Register


+5 V
+5 V
+5 V
+5 V
DATA INPUTS
A
B
C
D
D
Q
CLK
Q̄
CLR
A
B
C
D

JOB SHEET #2

B. Turn on power

C. Position the circuit inputs as shown in the first line of Table 2

TABLE 2

Inputs						**Outputs**			
CL	CLK	A	B	C	D	A	B	C	D
0	1	1	1	1	1				
1	1	0	1	1	1				
1	0	0	1	1	1				
1	1	1	1	1	1				
1	0	1	1	1	1				
0	1	1	1	1	1				
1	1	0	1	1	0				
1	0	0	1	1	0				
1	1	1	1	1	1				
1	0	1	1	1	1				
1	1	1	1	1	1				
0	1	1	1	1	1				

D. Record outputs A through D in Table 2

E. Continue steps C and D for each line of Table 2

F. Turn off power

G. Analyze the circuit by answering the following questions

1. How is the circuit cleared?

   ____

2. Is the register a series or parallel register?

   ____

   (NOTE: Discuss your results with the instructor before dismantling circuit. For a better understanding of the circuit, try various combinations of inputs and determine if the outputs are correct.)

H. Put equipment and materials away

MEMORY CIRCUITS
UNIT V

JOB SHEET #3 — CONSTRUCT AND ANALYZE A UNIVERSAL SHIFT REGISTER

I. Equipment and materials

   A. Power supply, 5 VDC regulated

   B. Four LEDs

   C. Ten resistors, 150 ohm

   D. Breadboard

   E. Nine SPST switches

   F. SPST switch, debounced

   (NOTE: A digital trainer may be used if it is equipped with the above components.)

   G. Circuit wiring

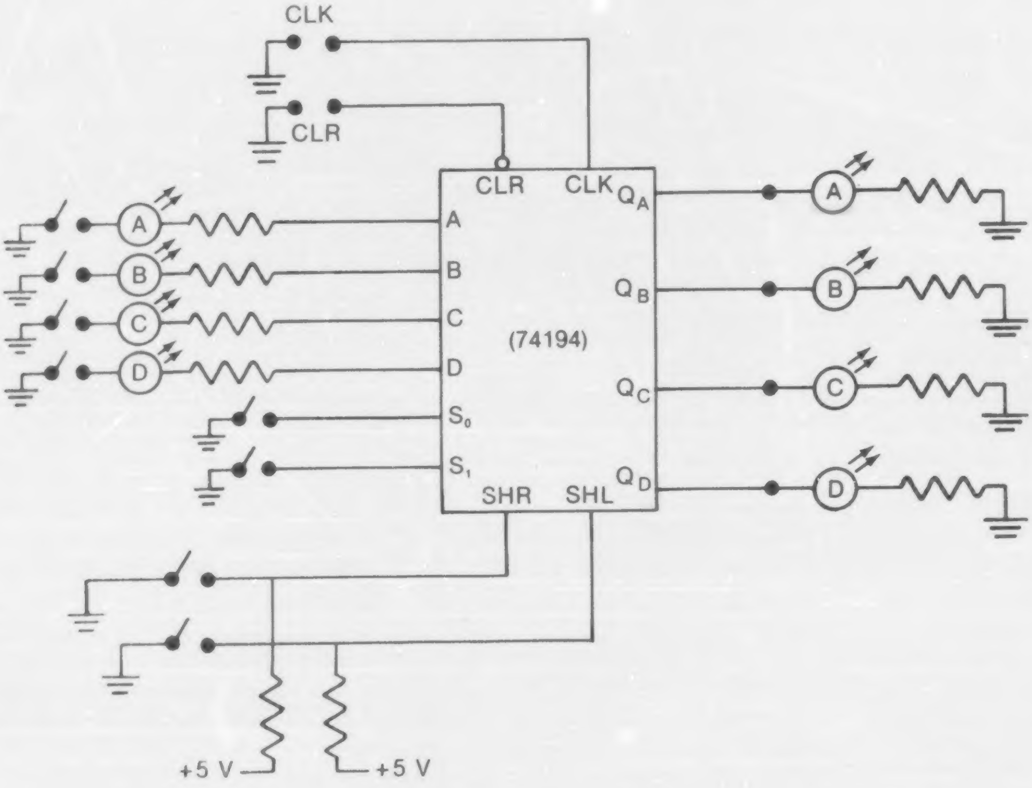
   H. Four-bit universal shift register, #74194

JOB SHEET #3

II. Procedure

A. Construct the circuit shown in Figure 3

FIGURE 3


CLK
CLR
CLR
CLK
A
B
C
D
S₀
S₁
SHR
SHL
(74194)
Q_A
Q_B
Q_C
Q_D
A
B
C
D
A
B
C
D
+5 V
+5 V

B. Turn on power

JOB SHEET #3

C. Position the circuit inputs as shown in Table 3

TABLE 3

Inputs										Outputs			
Mode		CL	SHL In	SHR In	Parallel				CLK #				
S0	S1				A	B	C	D		A	B	C	D
X	X	0	X	X	X	X	X	X					
1	1	1	X	X	0	1	0	0					
1	1	1	X	X	0	1	0	0	1				
1	0	1	X	0	X	X	X	X	2				
1	0	1	X	0	X	X	X	X	3				
1	0	1	X	0	X	X	X	X	4				
1	1	1	X	X	0	1	1	0					
1	0	1	X	X	0	1	1	0	5				
1	0	1	X	1	X	X	X	X	6				
1	0	1	X	1	X	X	X	X	7				
1	0	1	X	1	X	X	X	X	8				
1	0	1	X	1	X	X	X	X	9				
X	X	0	X	X	X	X	X	X					
1	1	1	X	X	1	0	0	0					
1	1	1	X	X	1	0	0	0	10				
1	1	1	X	0	1	0	0	0	11				
1	0	1	X	0	X	X	X	X	12				
1	0	1	X	1	X	X	X	X	13				
1	0	1	X	0	X	X	X	X	14				
1	0	1	X	0	X	X	X	X	15				
1	0	1	X	0	X	X	X	X	16				
0	1	1	0	X	X	X	X	X	17				
0	1	1	1	X	X	X	X	X	18				
0	1	1	0	X	X	X	X	X	19				
0	1	1	0	X	X	X	X	X	20				
0	1	1	0	X	X	X	X	X	21				
0	1	1	0	X	X	X	X	X	22				
1	1	1	X	X	0	1	1	0					
1	1	1	X	X	0	1	1	0	23				
0	0	1	X	X	X	X	X	X	24				
0	0	1	X	X	X	X	X	X	25				

(NOTE: Switch clock between numbered pulses.)

JOB SHEET #3

D. Record outputs A through D for all inputs in Table 3

E. Turn off power

F. Analyze the circuit by answering the following questions

1. When the shift register was in the shift right mode, why was the shift right input zero during clock pulses 2 through 4 but one during clock pulses 6 through 9?

   ____

   ____

2. Which input signal causes the shift register to shift right or left?

   ____

   ____

3. During clock pulses 24 and 25, did the output change?__________

   Why or why not?______________________________

   ____

   (NOTE: Discuss your results with the instructor before dismantling the circuit. For a better understanding of the circuit, try various combinations and study the results.)

G. Put equipment and materials away

MEMORY CIRCUITS
UNIT V

JOB SHEET #4 — CONSTRUCT AND ANALYZE A RANDOM-ACCESS MEMORY CIRCUIT

I. Equipment and materials

A. Power supply, 5 VDC regulated

B. Twelve LEDs

C. Fourteen resistors, 330 ohm, ¼ w

D. Breadboard

E. Ten SPST switches

(NOTE: A digital trainer may be used if it is equipped with the above components.)

F. Circuit wiring

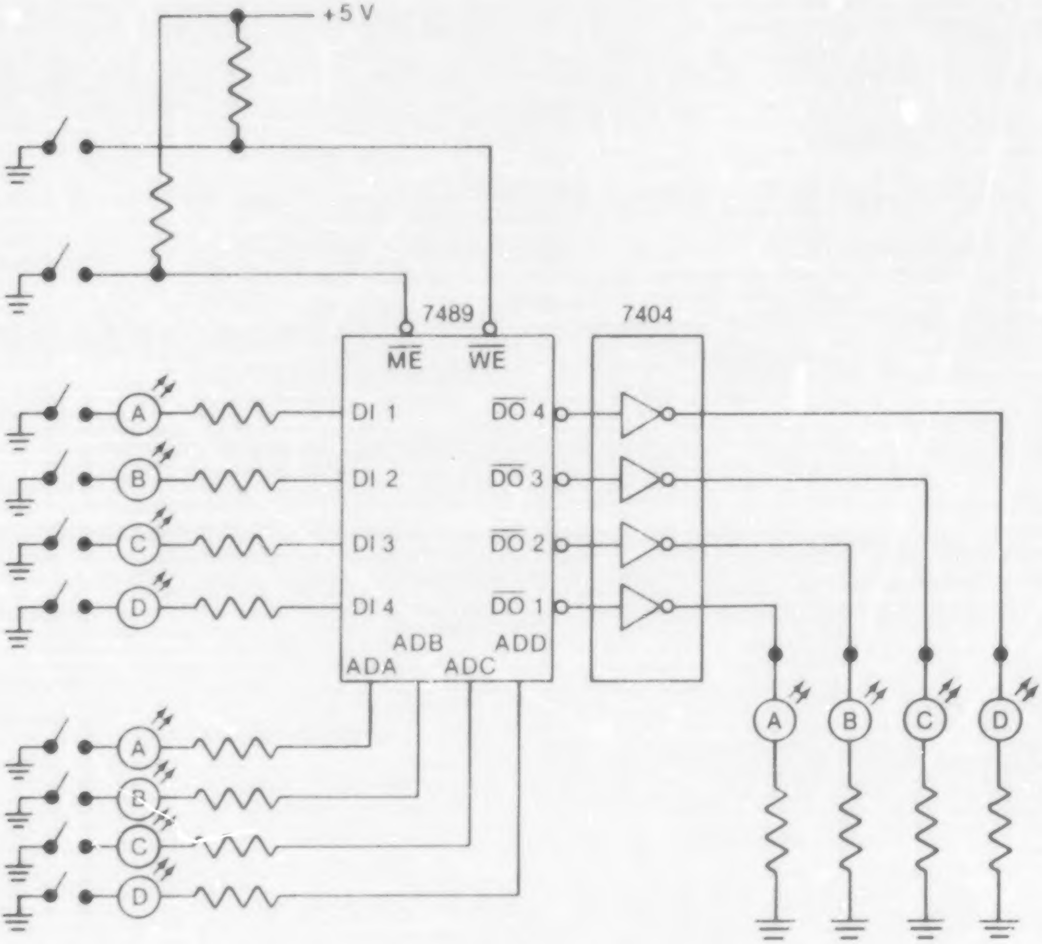
G. Hex inverter, #7404

JOB SHEET #4

II. Procedure

A. Construct the circuit shown in Figure 4

FIGURE 4


+5 V
7489
7404
ME
WE
DI 1
DI 2
DI 3
DI 4
DO 4
DO 3
DO 2
DO 1
ADA
ADB
ADC
ADD
A
B
C
D

B. Turn on power

C. Place the read/write switch in the write position

D. Place the memory enable switch in the disable position

JOB SHEET #4

E. Load the data for each of the sixteen word locations (addresses) shown in Table 4

TABLE 4

Address				Input				Output			
A	B	C	D	A	B	C	D	A	B	C	D
0	0	0	0	1	1	1	1				
0	0	0	1	1	1	1	0				
0	0	1	0	1	1	0	1				
0	0	1	1	1	1	0	0				
0	1	0	0	1	0	1	1				
0	1	0	1	1	0	1	0				
0	1	1	0	1	0	0	1				
0	1	1	1	1	0	0	0				
1	0	0	0	0	1	1	1				
1	0	0	1	0	1	1	0				
1	0	1	0	0	1	0	1				
1	0	1	1	0	1	0	0				
1	1	0	0	0	0	1	1				
1	1	0	1	0	0	1	0				
1	1	1	0	0	0	0	1				
1	1	1	1	0	0	0	0				

F. Place read/write switch in the read position

G. Set each address again

H. Record the outputs in Table 4

I. Explain whether the outputs correspond to the data that should be in the memory____

____

____

(NOTE: Discuss your results with the instructor before turning off the power.)

J. Put equipment and materials away

MEMORY CIRCUITS
UNIT V

TEST

NAME ____ SCORE __________________

1. Match terms associated with memory circuits to their correct definitions. Write the correct numbers in the blanks. Definitions are continued on the next page.

______a. Devices located outside the central processing unit

______b. Abbreviation for a *bi*nary digi*t*; information in the form of a one or zero stored in one computer cell

______c. One bit or group of bits at one address in a memory

______d. Memory that loses all its data when the power is removed

______e. Feeding one bit of data at a time into register or memory

______f. To copy information, transfer information, or record information in a certain location in a memory

______g. Information such as numbers, letters, symbols, or other information to be processed by a computer

______h. Pattern of characters that identifies a particular storage location

______i. Temporary storage unit for digital information

______j. Register in which the stored data can be moved to the right or left

______k. Memory that retains its data even if power is removed

______l. Area of an electronic device where information is stored

1. Register
2. Shift register
3. Serial loading
4. Parallel loading
5. Read
6. Data
7. Nonvolatile memory
8. Word
9. Address
10. Volatile memory
11. Peripherals
12. Bubble
13. Write
14. Memory
15. Bit

TEST

______m. Discrete area or domain in the field of a magnetic material

______n. To extract information from a memory

______o. Feeding several bits of data into register or memory at the same time

2. Select from the following list characteristics of shift registers. Write an "X" in each of the correct blanks.

______a. Hold information for temporary storage

______b. Generally have capacity of 4, 5, or 8 bits

______c. Use individual flip-flops rather than complicated IC circuitry

______d. Connect flip-flops in series

______e. May only be cleared by removing power

______f. Use memory characteristics of flip-flops

______g. Are available as integrated circuits (ICs)

3. Distinguish among characteristics of basic types of shift registers. Write an "S" in the blank before serial shift register, a "P" before parallel shift register, and a "U" before universal shift register.

______a. Can accept several bits of information at one time and enter them into the register by one clock pulse

______b. Can shift either left or right

______c. Can accept data serially or in parallel

______d. Can accept only one bit of data at a time

4. Distinguish between types of computer data storage. Write an "I" in the blanks before internal memory and an "E" before external data storage.

______a. Punched tape

______b. Disc and drum

______c. Semiconductor data storage

______d. Magnetic tape

______e. Punched cards

TEST

5. List types of computer memories.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

6. Distinguish among characteristics of memory circuits. Write the name or abbreviation for the type of internal memory described by each characteristic given below. Some blanks may have more than one answer.

____________ a. Can be programmed permanently if procedure obtained from manufacturer is followed

____________ b. Uses magnetic fields to control formation and movement of bubbles

____________ c. Retains data even if power is removed

____________ d. Loses all data when power to memory is removed

____________ e. Has permanent information programmed by manufacturer

____________ f. Can be erased and reprogrammed if procedure obtained from manufacturer is followed

____________ g. Is permanent and functions like a ROM once memory is programmed

____________ h. Uses permanent magnets so that memory is nonvolatile

____________ i. Is unalterable by user

____________ j. Can be erased electrically while IC is still in machine

____________ k. Allows more data storage per user than RAM

____________ l. Blows fuses selectively within the IC for the one-time write process

TEST

(NOTE: Test questions 7 and 8 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

7. Identify integrated circuit pin configurations.

8. Demontrate the ability to

   a. Construct and analyze a serial shift register.

   b. Construct and analyze a parallel shift register.

   c. Construct and analyze a universal shift register.

   d. Construct and analyze a random-access memory circuit.

MEMORY CIRCUITS
UNIT V

ANSWERS TO TEST

1. a. 11
   b. 15
   c. 8
   d. 10
   e. 3
   f. 13
   g. 6
   h. 9
   i. 1
   j. 2
   k. 7
   l. 14
   m. 12
   n. 5
   o. 4

2. a, b, d, f, g

3. a. P
   b. U
   c. U
   d. S

4. a. E
   b. E
   c. I
   d. E
   e. E

5. a. Random-access memory (RAM)
   b. Read-only memory (ROM)
   c. Programmable read-only memory (PROM)
   d. Erasable programmable read-only memory (EPROM)
   e. Electrically erasable programmable read-only memory (EEPROM)
   f. Bubble memory

ANSWERS TO TEST

6. a. PROM, EPROM, EEPROM
   b. Bubble
   c. EPROM, EEPROM
   d. RAM
   e. ROM
   f. EPROM, EEPROM
   g. PROM
   h. Bubble
   i. ROM
   j. EEPROM
   k. ROM
   l. PROM

7. Evaluated to the satisfaction of the instructor

8. Performance skills evaluated to the satisfaction of the instructor

SYSTEMS AND INTERFACING
UNIT VI

UNIT OBJECTIVE

After completing this unit, the student should be able to construct and analyze various digital and computer systems and interfaces. The student will show this knowledge by completing the assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with systems and interfacing to their correct definitions.
2. List elements of a digital system.
3. List types of integrated circuits used for digital circuitry.
4. List common digital systems.
5. List elements of a computer.
6. List types of computer information.
7. List basic functions within a data transmission system.
8. List types of A/D and D/A converters.
9. Select from a list characteristics of a discrete-type D/A converter.
10. Distinguish among characteristics of various A/D converters.
11. Identify integrated circuit pin configurations.
12. Demonstrate the ability to
    a. Construct and analyze a data transmission system.
    b. Construct and analyze a D/A converter.
    c. Construct and analyze an A/D converter.

SYSTEMS AND INTERFACING
UNIT VI

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Make transparencies.

  B. Provide students with objective sheet.

  C. Discuss unit and specific objectives.

  D. Provide students with information, assignment, and job sheets.

  E. Discuss information sheet.

  F. Demonstrate and discuss procedures outlined in assignment and job sheets.

  G. Give test.

II. Instructional materials

  A. Objective sheet

  B. Suggested activities

  C. Information sheet

  D. Transparency masters

    1. TM #1 — Digital System

    2. TM #2 — Computer System

    3. TM #3 — Data Transmission System

    4. TM #4 — Discrete-Type D/A Converter

  E. Assignment Sheet #1 — Identify Integrated Circuit Pin Configurations

  F. Answers to assignment sheet

  G. Job sheets

    1. Job Sheet #1 — Construct and Analyze a Data Transmission System

    2. Job Sheet #2 — Construct and Analyze a D/A Converter

    3. Job Sheet #3 — Construct and Analyze an A/D Converter

SUGGESTED ACTIVITIES

H. Test

I. Answers to test

III. Unit references

A. Barber, Alfred W. *Practical Guide to Digital Integrated Circuits*. West Nyack, New York: Parker Publishing Co., Inc., 1976.

B. Malvino, Albert P., and Donald P. Leach *Digital Principles and Applications*. New York: McGraw Hill, 1975.

C. Tokheim, Roger L. *Digital Electronics*. New York: McGraw Hill, 1979.

SYSTEMS AND INTERFACING
UNIT VI

INFORMATION SHEET

I. Terms and definitions

A. System — Group of circuits or devices interconnected to work together as a unit

B. Input — Information applied to a system

C. Output — Information taken out of a system

D. Subsystem — Smaller system or circuit within a system

E. Processor — Section of a system that acts upon information

F. Controller — Section of a system that guides or directs the processor; may be a part of the processor

G. Transmission lines — Connecting wires or circuits through which information is sent between systems or subsystems

H. Storage unit — Subsystem or circuitry in which data can be inserted, retained, and then retrieved for use

I. Central processing unit (CPU) — Part of a computer that contains the arithmetic unit and control device

J. Peripherals — Devices located outside the central processing unit

K. Multiplexer (MUX) — Device that selects one signal from a number of available signals for transmission over a single line

L. Demultiplexer (DeMUX) — Device that routes signals from one input to one or more outputs

M. Interface — Device or circuit that connects two or more circuits or units

N. Analog — Signal that can assume an infinite number of values between two limits

O. Digital — Signal that assumes one of two specific values

P. A/D converter — System that converts analog information to digital information

Q. D/A converter — System that converts digital information to analog information

INFORMATION SHEET

II. Elements of a digital system (Transparency #1; Assignment Sheet #1)

(NOTE: Integrated circuits [ICs] may have single logic gates such as AND, OR, or NOR and many subsystems such as counters or registers. Some ICs also include complete systems within one chip.)

- A. Input
- B. Processor
- C. Controller
- D. Transmission lines
- E. Storage units
- F. Output

III. Types of ICs used for digital circuitry

- A. Small scale integration (SSI)
- B. Medium scale integration (MSI)
- C. Large scale integration (LSI)
- D. Very large scale integration (VLSI)

IV. Common digital systems

- A. Calculators
- B. Computers
- C. Data transmission devices
- D. Error detectors
- E. Clocks
- F. Frequency counters
- G. Multimeters

V. Elements of a computer (Transparency #2)

- A. Input device
- B. Memory device

INFORMATION SHEET

- C. Arithmetic logic unit (ALU)
- D. Control device
- E. Output device

VI. Types of computer information

- A. Program
- B. Data

VII. Basic functions within a data transmission system

- A. Multiplexer (Transparency #3)
- B. Demultiplexer (Transparency #3)
- C. Error detector

VIII. Types of A/D and D/A converters

- A. Discrete (ladder)
- B. Integrated circuit

IX. Characteristics of a discrete-type D/A converter (Transparency #4)

1. Contains a resistive divider network of only two values
2. Contains input resistors that are all twice the value of the voltage divider resistors
3. Uses an operational amplifier as a summing network
4. Requires high accuracy, which is due to the precision resistive network
5. Requires high resolution, which is determined by how close the actual output voltage is in comparison to the theoretical value

X. Characteristics of various A/D converters

- A. Counter-ramp A/D converter
    1. Contains input of a single variable voltage

INFORMATION SHEET

2. Contains a comparator, AND gates, counter, and a D/A converter

   (NOTE: The counter-ramp A/D converter receives a voltage input to the comparator. This voltage is compared with the feedback signal from the D/A converter. If the input signal is higher than the feedback signal, the counter counts a binary 0001. This process continues until the feedback signal is higher than the input.)

B. Ramp-type A/D converter

   1. Utilizes a ramp generator rather than a D/A converter

   2. Takes a relatively long time to count to higher voltages

      (NOTE: The ramp-type converter utilizes a ramp pulse or sawtooth. As the voltage increases, the clock pulses are allowed to pass and are counted in binary. Once the input value is reached, the comparator does not allow more clock pulses to pass. Thus, the analog value is converted to a binary value.)

C. Successive approximation A/D converter

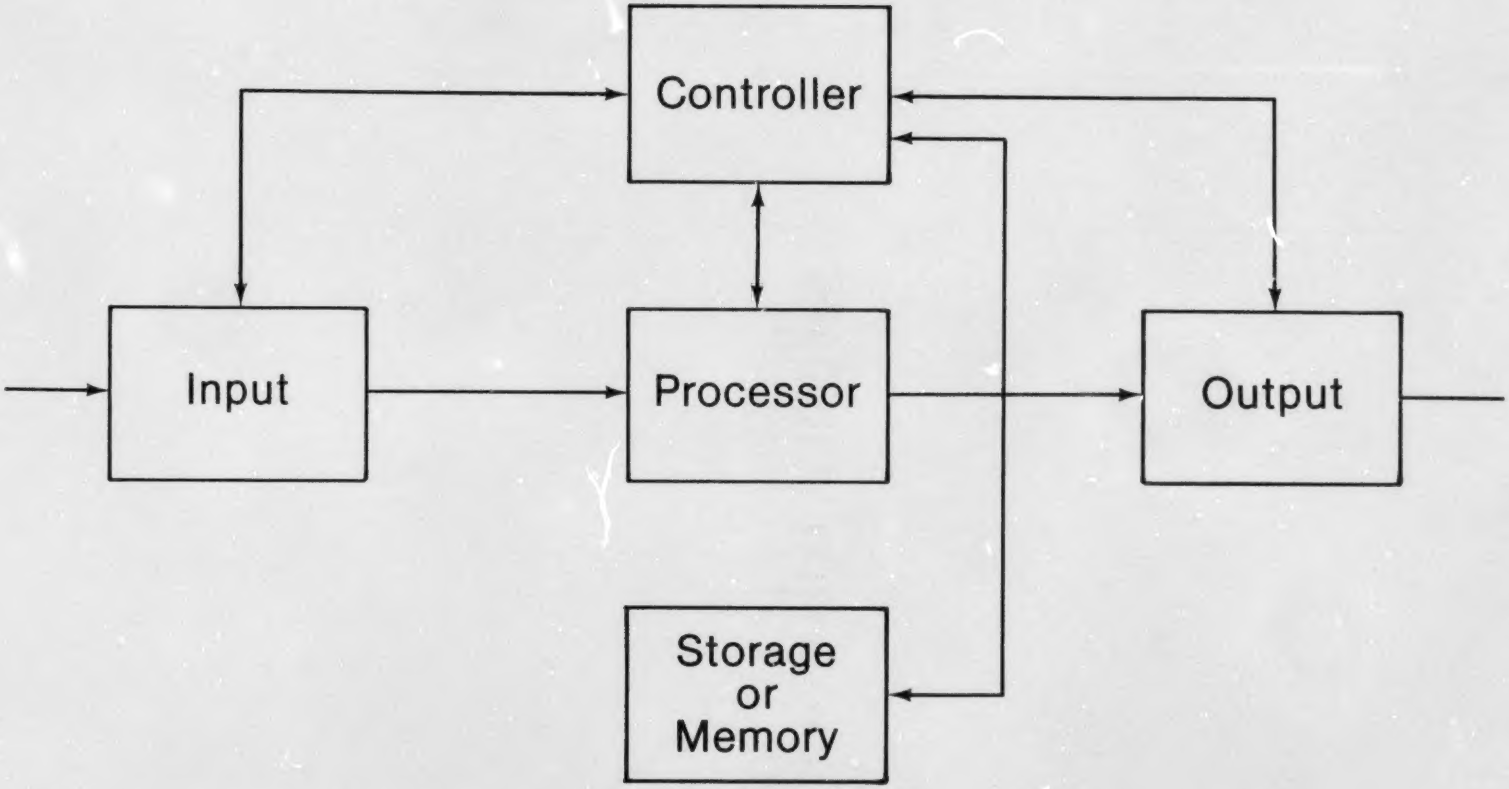
   (NOTE: This type converter is much more widely used than other types.)

   1. Is much faster than other types

   2. Utilizes a successive approximation logic unit rather than the AND gates and counter

      (NOTE: In the successive approximation A/D converter, the D/A converter approximates the binary value of information fed through it. The successive approximation unit determines whether the most significant digit [MSD] is too high or too low. This process continues until the successive approximation unit has correctly determined each digit of the binary value.)

Digital System



Controller

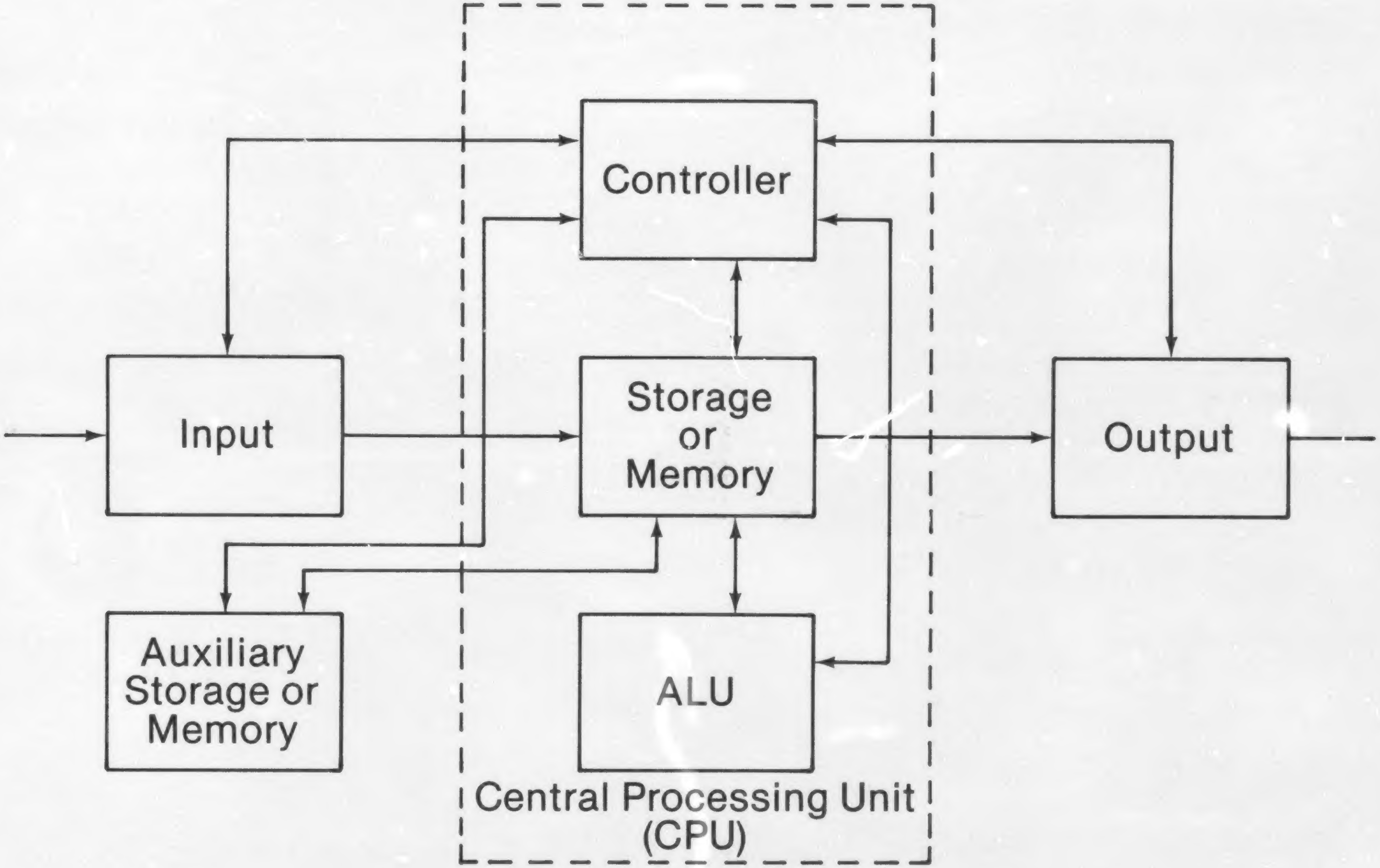
Input

Processor

Output

Storage
or
Memory

Computer System



Controller

Input

Storage or Memory

Output

Auxiliary Storage or Memory

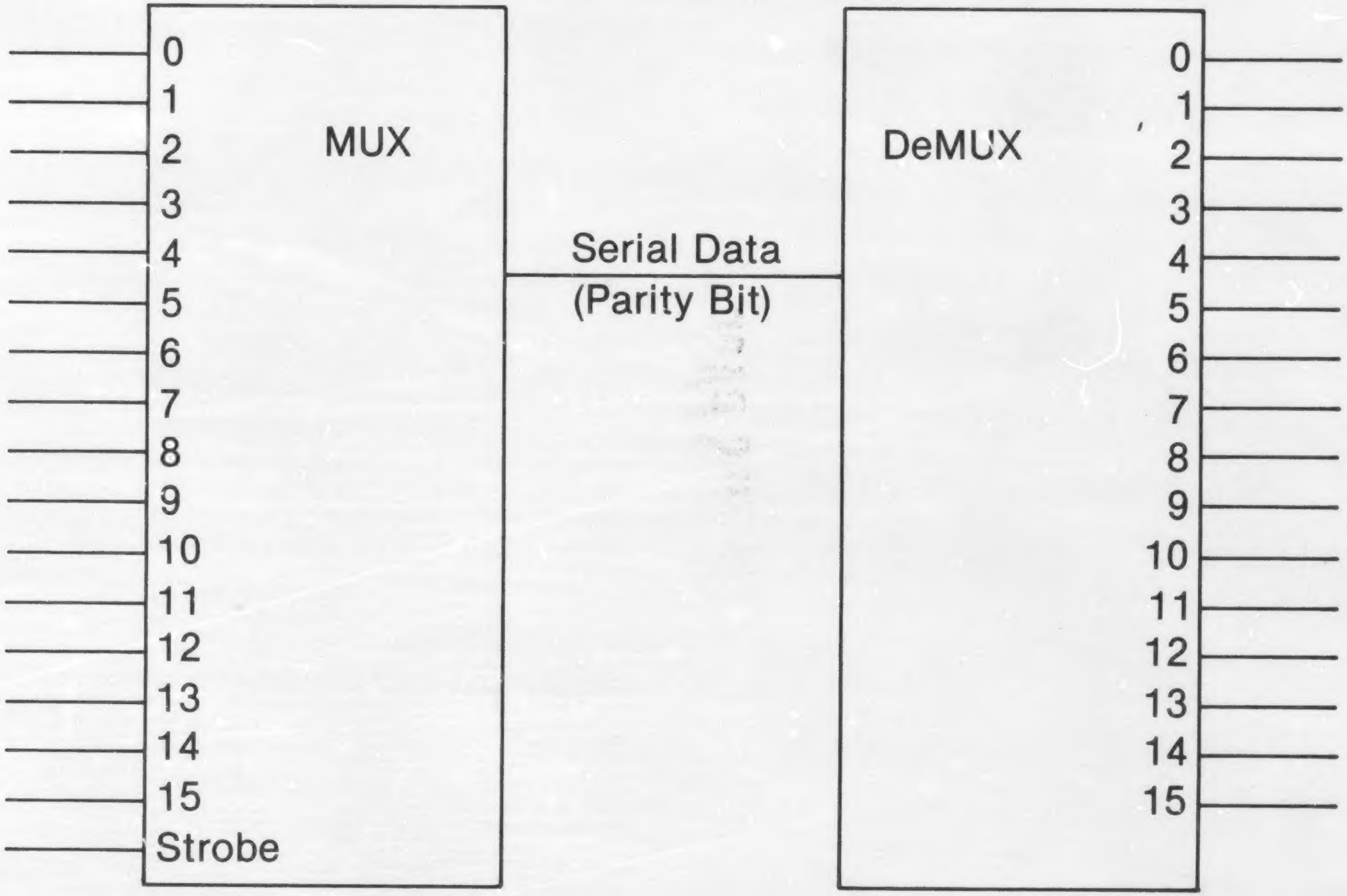
ALU

Central Processing Unit (CPU)

TM #2

AIE - 221-B

Data Transmission System


0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Strobe
MUX
Serial Data
(Parity Bit)
DeMUX
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

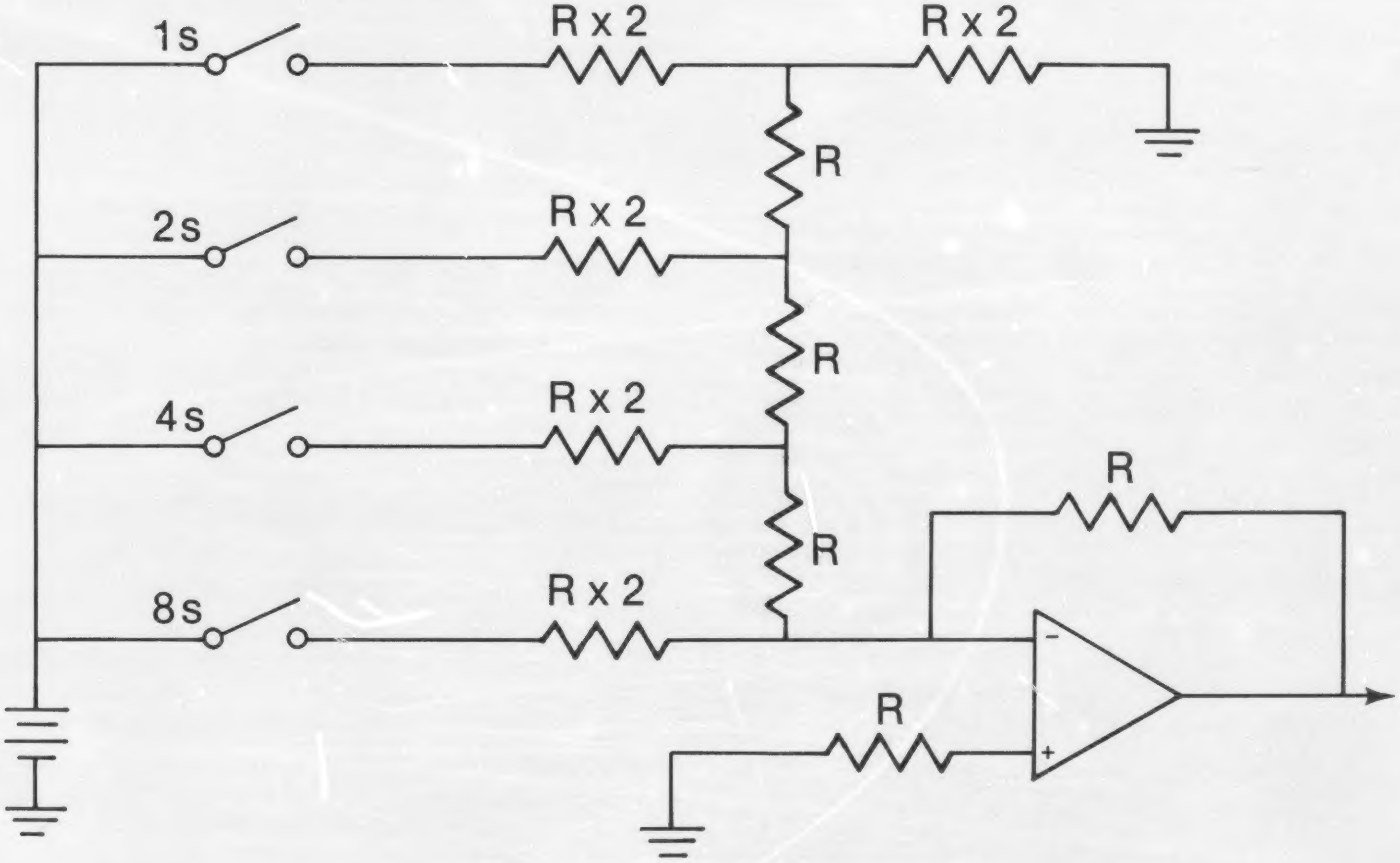
TM #3

303

304

AIE - 223-B

Discrete-Type D/A Converter


1s
2s
4s
8s
R x 2
R x 2
R x 2
R x 2
R x 2
R
R
R
R
R
–
+

TM #4

AIE - 225-B

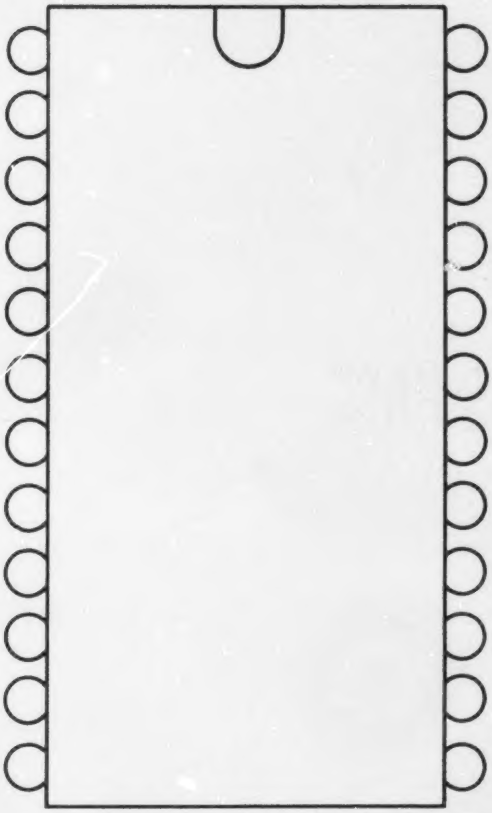
SYSTEMS AND INTERFACING
UNIT VI

ASSIGNMENT SHEET #1 — IDENTIFY CIRCUIT PIN CONFIGURATIONS

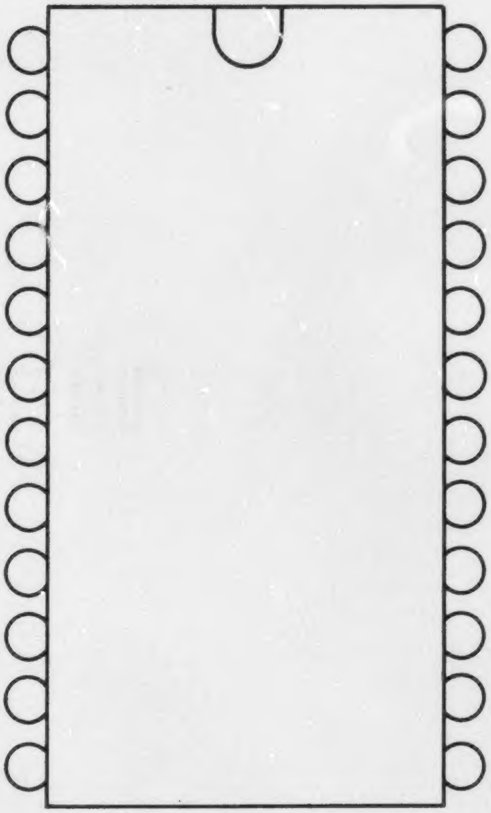
NAME ______________________________ SCORE ______________

A technician encountering new and various circuit designs will also encounter new and different ICs. The new ICs you will be using in this unit are shown below. Various data books show the pin configurations and list other characteristics.

On the following diagrams, identify the function and pin configuration of each IC.



A. 74150______________________________

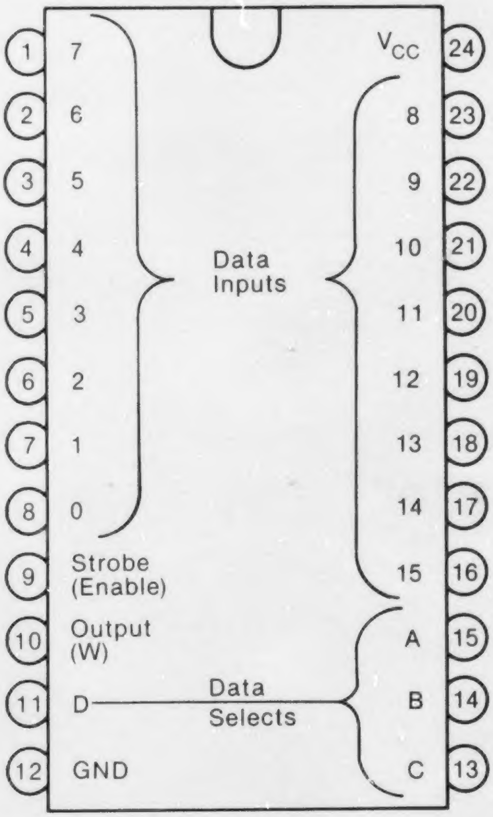


B. 74154______________________________

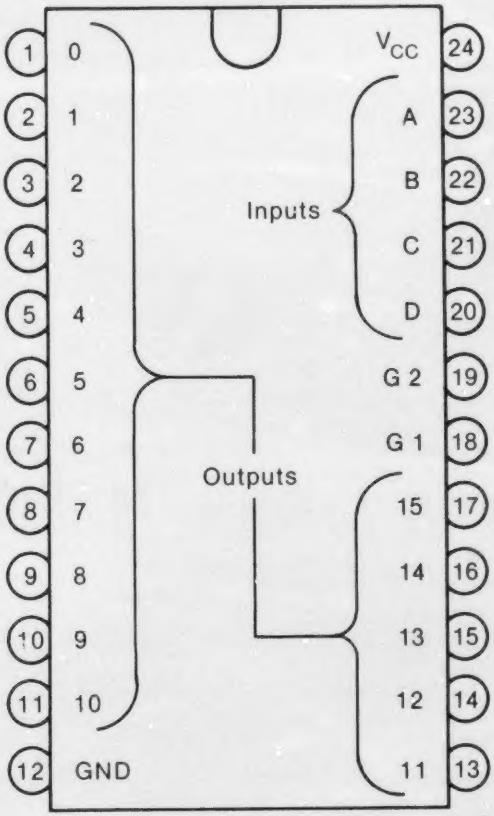
SYSTEMS AND INTERFACING
UNIT VI

ANSWERS TO ASSIGNMENT SHEET

Assignment Sheet #1


1 7
2 6
3 5
4 4
5 3
6 2
7 1
8 0
9 Strobe (Enable)
10 Output (W)
11 D
12 GND
Data Inputs
Data Selects
V_{CC} 24
8 23
9 22
10 21
11 20
12 19
13 18
14 17
15 16
A 15
B 14
C 13

A. 74150
16/1 selector multiplexer


1 0
2 1
3 2
4 3
5 4
6 5
7 6
8 7
9 8
10 9
11 10
12 GND
Outputs
Inputs
V_{CC} 24
A 23
B 22
C 21
D 20
G 2 19
G 1 18
15 17
14 16
13 15
12 14
11 13

B. 74154
4/16 demultiplexer

SYSTEMS AND INTERFACING
UNIT VI

JOB SHEET #1 — CONSTRUCT AND ANALYZE A DATA TRANSMISSION SYSTEM

I. Equipment and materials

A. Power supply, 5 Volts DC

B. LED

C. Resistor, 125 ohm, 1/4 watt

D. Seven-segment display

E. Counter, #7493 or equivalent

F. Multiplexer, #74150 or equivalent

G. Inverter, #74074 or equivalent

H. Demultiplexer, #74154 or equivalent

I. Breadboard

(NOTE: A digital trainer may be used if it is properly equipped.)

J. Two switches, debounced

K. Circuit wiring

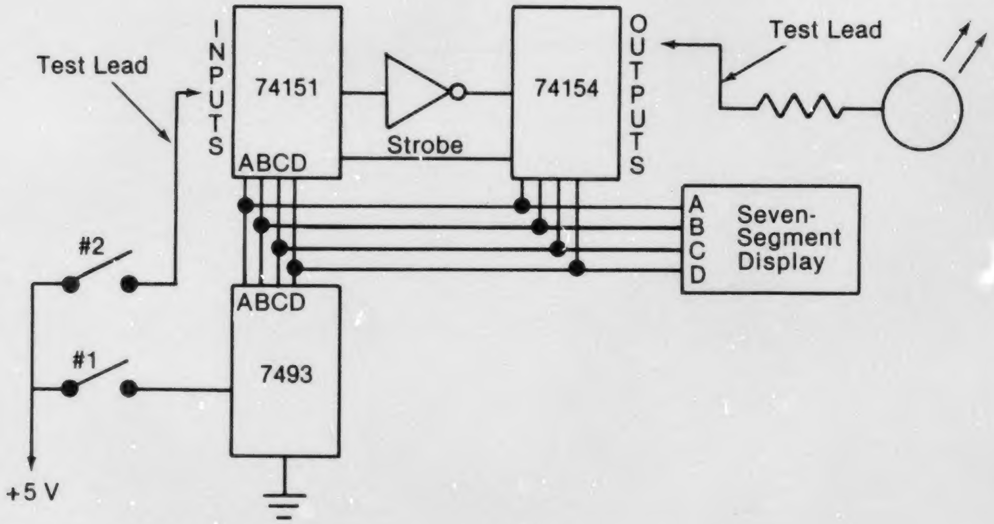
L. Two test leads

JOB SHEET #1

II. Procedure

A. Construct the circuit shown in Figure 1

FIGURE 1


Test Lead
INPUTS
74151
ABCD
Strobe
74154
OUTPUTS
Test Lead
A
B
C
D
Seven-Segment Display
#2
#1
ABCD
7493
+5 V

B. Turn on power

C. Connect the test lead from switch 2 to pin 8 of the multiplexer

D. Connect the test lead from the LED to pin 1 of the demultiplexer

E. Sequence switch 1 until decimal 0 appears on the display

(NOTE: This configuration selects channel 0 for transmission of data from switch 2. Check a handbook if necessary to determine the segment display that represents decimal 0.)

F. Sequence switch 2 several times and observe the LED

G. Describe the relationship between the transmission signal and the LED indications

JOB SHEET #1

H. Connect the test lead from switch 2 to pin 7 of the multiplexer

I. Connect the test lead from the LED to pin 2 of the demultiplexer

J. Sequence switch 1 until decimal 1 appears on the display

K. Record the channel of the multiplexer that will be used for transmission in this configuration____

L. Record in Table 1 the multiplexer and demultiplexer pins that you think should be used to produce each of the decimal numerals

TABLE 1

Display	74150 Pin	74154 Pin
0	8	1
1	7	2
2		
3		
4		
5		
6		
7		
8		
9		

M. Check your predictions for decimal numerals 4, 6, and 9 by making the indicated connections and observing the LED

(NOTE: Discuss your results with the instructor.)

N. Turn off power

O. Put away equipment and materials

SYSTEMS AND INTERFACING
UNIT VI

JOB SHEET #2 — CONSTRUCT AND ANALYZE A D/A CONVERTER

I. Equipment and materials

   A. Two power supplies, 25 VDC variable regulated

   B. Power supply, 5 VDC regulated

   C. Breadboard

   D. Four SPST switches

   E. Resistor, 10 kohm

   F. Resistor, 150 kohm

   G. Resistor, 75 kohm

   H. Variable resistor, 50 kohm

   I. Variable resistor, 20 kohm

   J. Operational amplifier, #741

   K. Multimeter

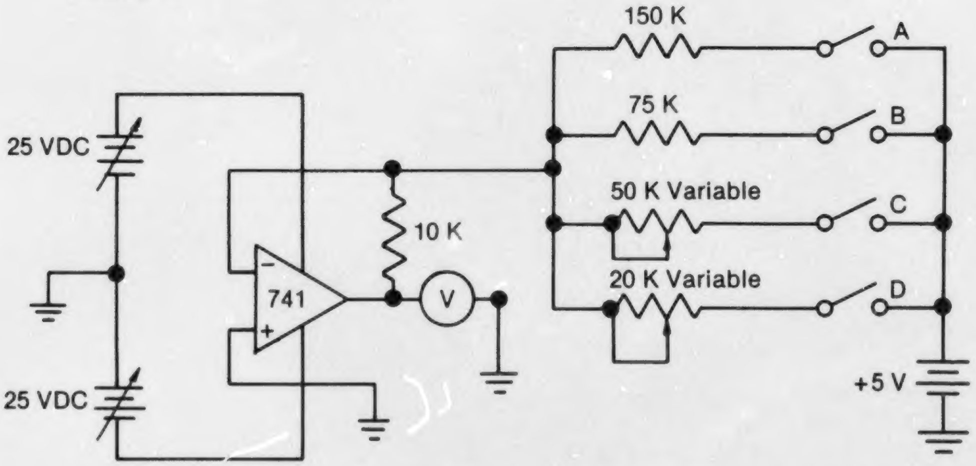
   L. Circuit wiring

JOB SHEET #2

II. Procedure

A. Construct the circuit shown in Figure 2

FIGURE 2


150 K
A
75 K
B
25 VDC
50 K Variable
C
10 K
741
V
20 K Variable
D
+5 V
25 VDC

(NOTE: Turn on the V_{CC} power of the operational amplifier before applying any input signal.)

B. Calculate the voltage out of the op-amp in each position shown in Table 2

JOB SHEET #2

C. Record your calculated values in the table

TABLE 2

Input				Output	
A	B	C	D	Calculated	Measured
0	0	0	0		
0	0	0	1		
0	0	1	0		
0	0	1	1		
0	1	0	0		
0	1	0	1		
0	1	1	0		
0	1	1	1		
1	0	0	0		
1	0	0	1		
1	0	1	0		
1	0	1	1		
1	1	0	0		
1	1	0	1		
1	1	1	0		
1	1	1	1		

D. Turn on power

E. Position the switches in the input positions given in Table 2

F. Measure the output voltage of each switch position

G. Record the measured output in the table

JOB SHEET #2

H. Analyze the circuit by answering the following questions

1. Which components in the circuit make up the summing circuit?

   ____

2. Can other components or circuits be used for a summing circuit?

   ____

I. Turn off power

(NOTE: Discuss your results with the instructor.)

J. Put all equipment and materials away

SYSTEMS AND INTERFACING
UNIT VI

JOB SHEET #3 — CONSTRUCT AND ANALYZE AN A/D CONVERTER

I. Equipment and materials

   A. Power supply, 25 VDC regulated

   B. Power supply, 5 VDC regulated

   C. Four LEDs

   D. Four resistors, 150 ohm

   E. Breadboard

   F. SPST switch, debounced

   (NOTE: A digital trainer may be used if it is equipped with the above components.)

   G. Circuit wiring

   H. Resistor, 47 kohm

   I. Resistor, 150 kohm

   J. Resistor, 75 kohm

   K. Variable resistor, 50 kohm

   L. Variable resistor, 20 kohm

   M. Two resistors, 10 kohm

   N. Two operational amplifiers, #1458

   O. Zener diode, 4 V

   P. Four-bit binary counter, #7493

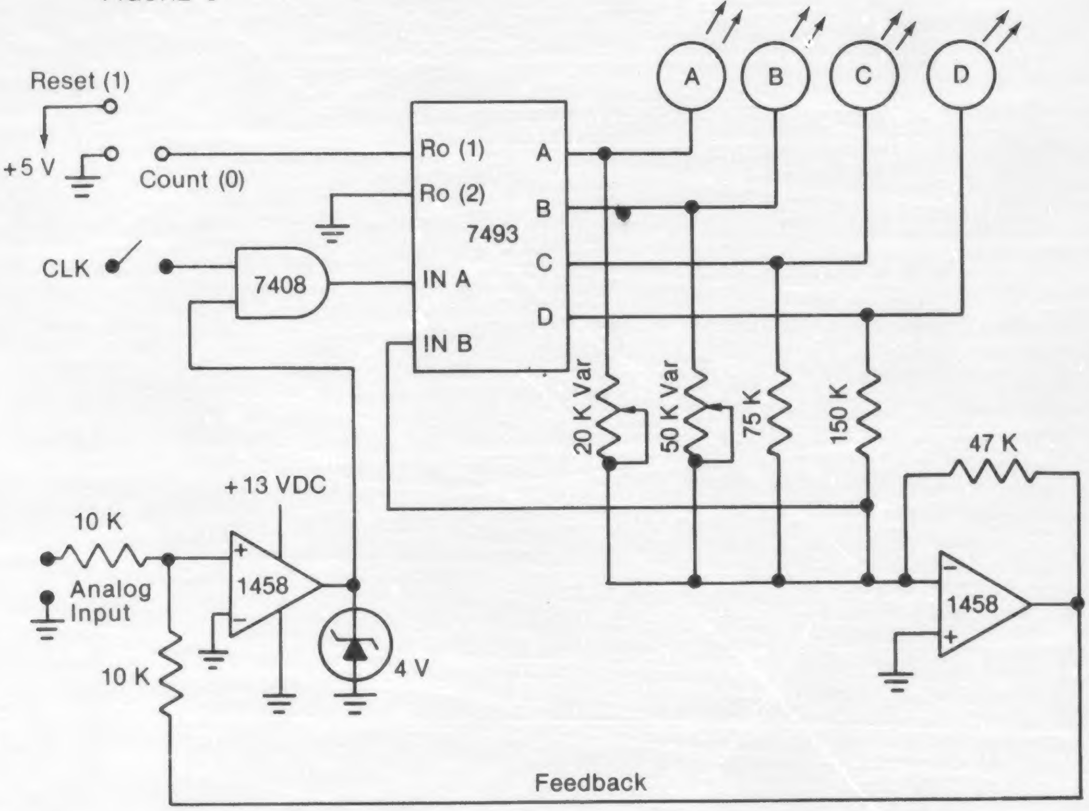
   Q. Two-input AND gate, #7408

JOB SHEET #3

II. Procedure

A. Construct the circuit shown in Figure 3

FIGURE 3


Reset (1)
+5 V
Count (0)
CLK
7408
Ro (1)
Ro (2)
7493
IN A
IN B
A
B
C
D
20 K Var
50 K Var
75 K
150 K
47 K
+13 VDC
10 K
Analog Input
1458
10 K
4 V
1458
Feedback

JOB SHEET #3

B. Analyze the circuit by answering the following questions

1. Which portion of the circuit is the D/A converter?

2. Which portion of the circuit is the summing circuit?

3. Which portion of the circuit is the comparator circuit?

4. What other components or circuits make up the A/D converter?

C. Turn on power

D. Apply the required power to the analog input to obtain the designated binary outputs in Table 3

JOB SHEET #3

E. Record the analog inputs in the table

TABLE 3

Output				Input
A	B	C	D	Voltage
0	0	0	0	
0	0	0	1	
0	0	1	0	
0	0	1	1	
0	1	0	0	
0	1	0	1	
0	1	1	0	
0	1	1	1	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

F. Turn off power

G. Compare the readings in Table 3 with those in Table 2 of Job Sheet #2

JOB SHEET #3

H. Record your observations

____

____

(NOTE: Discuss your results with the instructor.)

I. Put equipment and materials away

SYSTEMS AND INTERFACING
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TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with systems and interfacing to their correct definitions. Write the correct numbers in the blanks. Definitions are continued on the next page.

______a. Subsystem or circuitry in which data can be inserted, retained, and then retrieved for use

______b. Signal that can assume an infinite number of values between two limits

______c. System that converts analog information to digital information

______d. Device that selects one signal from a number of available signals for transmission over a single line

______e. Information taken out of a system

______f. Device that routes signals from one input to one or more outputs

______g. Group of circuits or devices interconnected to work together as a unit

______h. Smaller system or circuit within a system

______i. Device or circuit that connects two or more circuits or units

______j. Signal that assumes one of two specific values

______k. System that converts digital information to analog information

______l. Part of a computer that contains the arithmetic unit and control device

______m. Section of a system that acts upon information

1. Analog
2. Digital
3. Input
4. Output
5. System
6. Subsystem
7. A/D converter
8. D/A converter
9. Peripherals
10. Central processing unit (CPU)
11. Multiplexer (MUX)
12. Demultiplexer (DeMUX)
13. Interface
14. Processor
15. Transmission lines
16. Controller
17. Storage unit

TEST

______n. Devices located outside the central processing unit

______o. Information applied to a system

______p. Connecting wires or circuits through which information is sent between systems or subsystems

______q. Section of a system that guides or directs the processor; may be a part of the processor

2. List the elements of a digital system.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

3. List types of ICs used for digital circuitry.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

4. List five common digital systems.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

TEST

5. List elements of a computer.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

6. List types of computer information.

a. ______________________________

b. ______________________________

7. List basic functions within a data transmission system.

a. ______________________________

b. ______________________________

c. ______________________________

8. List types of A/D and D/A converters.

a. ______________________________

b. ______________________________

9. Select from the following list characteristics of a discrete-type D/A converter. Write an "X" in the blank before each correct characteristic.

______a. Contains a resistive divider network of only two values

______b. Contains input resistors that are all twice the value of the voltage divider resistors

______c. Contains input resistors that all are half the value of the voltage divider resistors

______d. Uses an operational amplifier as a summing network

______e. Requires high accuracy, which is due to the precision resistive network

______f. Uses a ramp generator

TEST

_____g. Requires high resolution, which is determined by how close the actual output voltage is in comparison to the theoretical value

10. Distinguish among characteristics of various A/D converters. Place a "C" before each characteristic of a counter-ramp A/D converter, an "R" before each characteristic of a ramp-type A/D converter, and an "S" before each characteristic of a successive approximation A/D converter.

_____a. Utilizes a ramp generator rather than a D/A converter

_____b. Is much faster than other types

_____c. Takes a relatively long time to count to higher voltages

_____d. Utilizes the successive approximation logic unit rather than the AND gates and counter

_____e. Contains a comparator, AND gates, counter, and a D/A converter

_____f. Contains input of a single variable voltage

(NOTE: Test questions 11 and 12 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

11. Identify integrated circuit pin configurations.

12. Demonstrate the ability to

    a. Construct and analyze a data transmission system.

    b. Construct and analyze a D/A converter

    c. Construct and analyze an A/D converter.

SYSTEMS AND INTERFACING
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ANSWERS TO TEST

1. a. 17
   b. 1
   c. 7
   d. 11
   e. 4
   f. 12
   g. 5
   h. 6
   i. 13
   j. 2
   k. 8
   l. 10
   m. 14
   n. 9
   o. 3
   p. 15
   q. 16

2. a. Input
   b. Processor
   c. Controller
   d. Transmission lines
   e. Storage units
   f. Output

3. a. Small scale integration (SSI)
   b. Medium scale integration (MSI)
   c. Large scale integration (LSI)
   d. Very large scale integration (VLSI)

4. Answer should include any five of the following
   a. Calculators
   b. Computers
   c. Data transmission devices
   d. Error detectors
   e. Clocks

ANSWERS TO TEST

f. Frequency counters

g. Multimeters

5. a. Input device

b. Memory device

c. Arithmetic logic unit (ALU)

d. Control device

e. Output device

6. a. Program

b. Data

7. a. Multiplexer

b. Demultiplexer

c. Error detector

8. a. Discrete (ladder)

b. Integrated circuit

9. a, b, d, e, g

10. a. R d. S

b. S e. C

c. R f. C

11. Evaluated to the satisfaction of the instructor

12. Performance skills evaluated to the satisfaction of the instructor